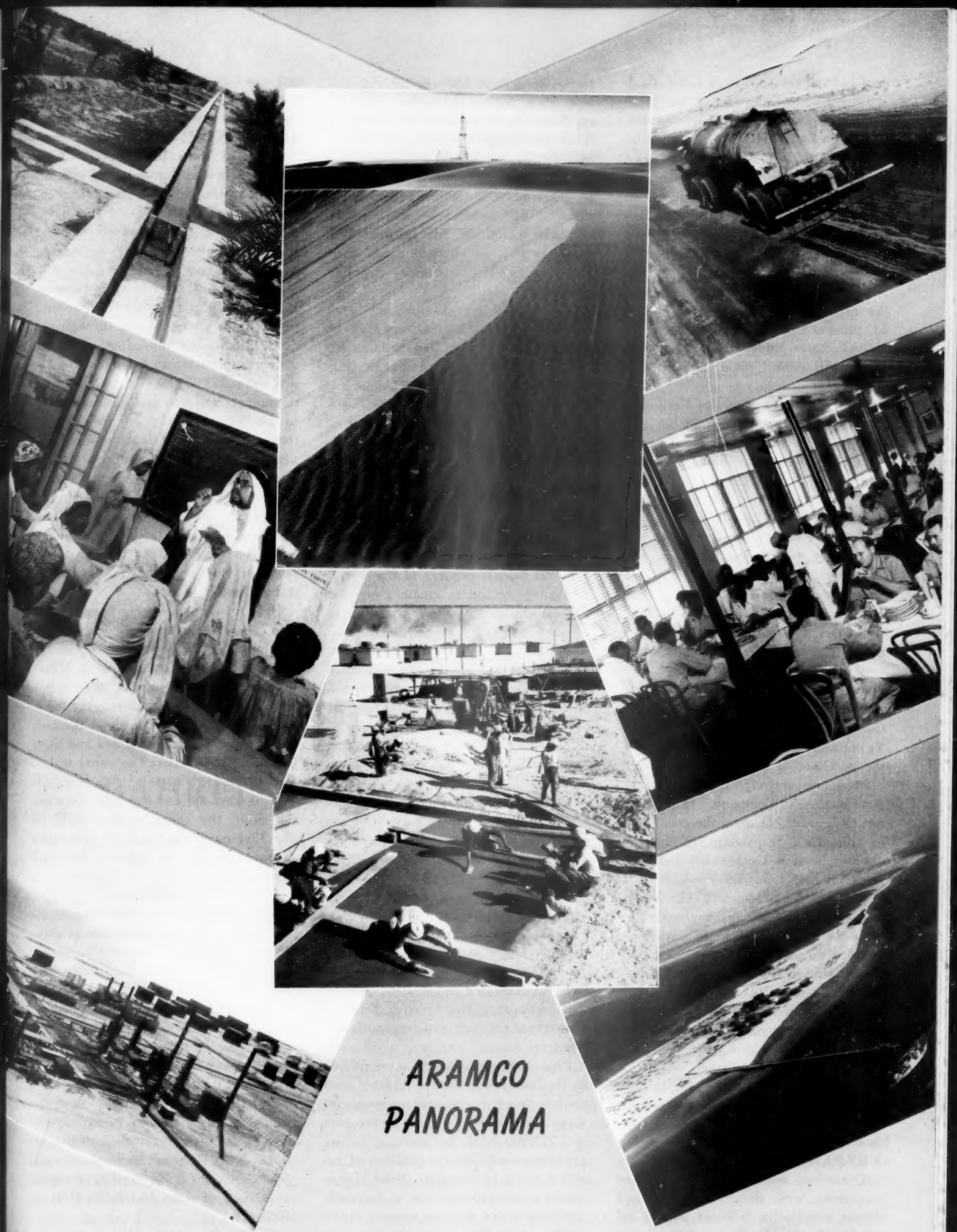


ARAMCO PANORAMA

LEFT

Top: Irrigation project at Al Hassa.

Center: An English class at a company school.

Bottom: Refinery at Ras Tanura.

CENTER

Top: Typical Dammam scene.

Bottom: Modern methods and Arab workers produce housing at Abqaiq.

RIGHT

Top: Oiling the road at Abqaiq.

Center: American dining room—food from U. S.

Bottom: Storage tanks and docks, Ras Tanura Peninsula.

acquired the oil concession there. Back in 1922 the treaties of Mohammerah between Iraq and Nejd (that was Ibn Saud's kingdom at that time) and the Kuwait-Nejd Boundary Convention had established two neutral zones, one of the practical effects of which was to give Ibn Saud and the Sheikh of Kuwait each a one-half interest in one zone. It was the interest of the Sheikh of Kuwait which was leased to the American Independent group. This is the first large-scale movement abroad by independent oil companies of the United States under an arrangement which will permit some fair-sized operations.

Standard Oil Company of California came into the Saudi Arabian oil picture in 1933, when the firm obtained from H. M. King Ibn Saud a concession covering eastern Saudi Arabia. The Texas Company acquired a half interest in these operations in 1936, and four years ago the name was changed to Arabian American Oil Company. After the opening of the Dammam field in 1938, more drilling opened up the Abqaiq and Abu Hadriya fields. Production in Saudi Arabia now is about 425,000 B/D, and proven reserves are calculated at 7 billion barrels.

In March, last year, Standard Oil Company (New Jersey) and Socony-Vacuum entered into an agreement for the purchase of a 30 and 10 per cent interest, respectively, in the Arabian American Oil Company. The agreement is contingent upon the conclusion of litigation respecting an interest claimed by C. S. Gulbenkian under the so-called Red Line Agreement.

Egypt also has some oil. The Anglo-Egyptian Oil Company is producing some 36,000 B/D, which is only about half the amount the country itself consumes. Proved reserves are 113 million barrels.

The total reserves of all these Middle Eastern fields, as is noted before, amount to nearly 35 billion barrels as compared with 22 billion barrels for the United States. And despite the scale of developments to date, these Middle Eastern fields have been scarcely touched.

PREPARATION FOR WORK

But when operating conditions are compared with those in the United States a radically different picture develops. The Middle East is desert country. Only three inches of rain fall a year, and in summer the thermometer climbs to around 130 degrees Fahrenheit. Then, during the period of greatest heat, the monsoons come in from India, which means working not only in heat but in damp heat.

Roads, wharfs and housing have to be constructed. Food and other necessities of life have to be imported in immense quantities. All spiritual and social as well as physical needs have to be provided. The country supplies nothing.

At Dhahran, for example, the Arabian American Oil Company had to spend almost $100 million building its camp. With some 3,000 Americans and 14,000 Arabs to supply, the commissary is a tremendous project. The head storekeeper told me last year that it has 550,000 items on its books — everything that a family will use, from toothpaste to lingerie, shoes, stockings, pins and needles. The commissary must have these necessities because there is no other place to get them.

At Abadan, where Anglo-Iranian has built the largest refinery in the world, that company had to create a city for 130,000 people. Such is the extent to which a company operating in this area has to go merely to get ready to work.

And that isn't all. People with little or no prior acquaintance with disease prevention or technical work have to be trained. Medical facilities have to be provided, schools established. At Abadan, a college has been built to accommodate 1,200 or more students. At Dhahran, where operations have not been under way very long, the program so far has reached only the elementary and training school stage.

OPERATION COSTS

Certain other operating costs are comparatively low, or have been so far. The fields are highly productive, and drilling depths generally are shallow. On the other hand, although the area is by far the best situated for supplying the Eastern Hemisphere, distances to markets are long and transportation costs are high.

Pipe line capacity of some 90,000 B/D already has been completed, and enough more is in various stages of progress to bring the total in prospect to 1,715,000 B/D. But here, again, we are confronted with the problem of immense capital investment if the Middle East's great supplies are to be made available where they are needed. Trans-Arabian Pipe line, or Tapline for short, which is to carry oil from the Persian Gulf to the eastern Mediterranean, entails an estimated investment of about $200 million. More than $70 million already has been spent.

TANKERS OR PIPE LINES?

Questions have been raised as to whether it would not be better to build tankers instead of pipe lines. The answer is simple.

To replace the proposed Tapline transportation by tankers, to take a specific example, would require 102 T-2 tankers operating steadily between Ras Tanura in the Persian Gulf, around the Arabian Peninsula and through the Suez Canal. The pipe line, pumping stations and servicing machinery represent about 323,000 tons of steel, whereas the tankers and port facilities necessary to load them would require 565,400 tons. Furthermore, approximately 25 per cent of the pipe required for the line is already on the ground in Arabia. With this amount deducted, the additional steel requirement for the pipe line and facilities becomes somewhat less than 263,000 tons, or about 302,400 tons less than would be required for the tankers.

Here is another striking comparison: The horsepower required for pump stations would be about 78,000, as compared to 600,000 for the tankers. Moreover, it would take about three times as much manpower to operate the tankers as the pipe line. The haul through the Persian Gulf, the Red Sea and Suez Canal is 3,500 miles. The canal toll is about 18 cents a barrel. If the Marshall Plan is kept up, and the pipe lines are not built, the added expense will be just that much more for the American taxpayer to pay in meeting Europe's needs for oil.

INCREASING NEEDS

How large are the world's needs today? Well, the United States at present requires about 5,900,000 barrels a day, and the rest of the hemisphere about 1,000,000. Eastern Hemisphere requirements are 2,600,000 barrels. As previously noted, current withdrawals in the Middle East are only 1,100,000 B/D, or less than half the amount necessary to supply that Hemisphere.

By 1960, it is estimated that the United States will need 7,600,000, and this hemisphere as a whole 9,200,000 B/D. The Eastern Hemisphere will need 3,900,000 B/D, making a world-wide need of some 13,100,000 B/D by 1960.

Europe has little oil of its own. Western Hemisphere supplies are limited. Middle East oil therefore must be

made available, and any important delay will place an increasing strain on the supplies of our own hemisphere.

AGRICULTURAL ECONOMY AND INDUSTRIALIZATION

The peace of the world is tied to this project. Meanwhile, it is of great social and economic significance to the Middle East itself.

Taking it as a whole, this development is one of the greatest of an industrial character in modern history. Its potential social effects are equally great. On the whole, the area has low living standards, but the means are at hand for raising those standards markedly. Much of the area's extreme poverty results from its restricted agricultural economy and can be relieved by industrialization. The development of jobs can make over the status of thousands of families in a short time, and over a period of years can lift whole populations to a greatly improved level of living.

IMPROVEMENTS UNDERWAY

Right now important strides are betaken in that direction. In Iran an economic planning group working with the government is busy with programs for roads, hospitals and agricultural improvements. Another is getting under way in Iraq, and a similar movement is being pressed in Turkey.

These programs are based on building from the ground up. By bringing the agricultural system up to modern standards and thereby getting the people decently fed, minds and bodies can respond to training, and their spirits can better resist the siren songs of the collectivists.

EXAMPLE OF POSSIBILITIES

The Saudi Arabia government is dosome fine work. At El Kharj, they conceived the idea of an irrigation and model farm project. They talked their plans over with Arabian American and, as a result, some Texas A & M graduates were brought to El Kharj and put to work on the job. This was right in the middle of the desert. Some 4,000 acres are now being irrigated and with remarkable results. In fact, the experiment has been so successful that the Saudi Arabian government is now surveying other food raising possibilities in cooperation with Arabian American. The government now has a staff of 25 or more American agriculturists in its employ and is starting four additional demonstration farms.

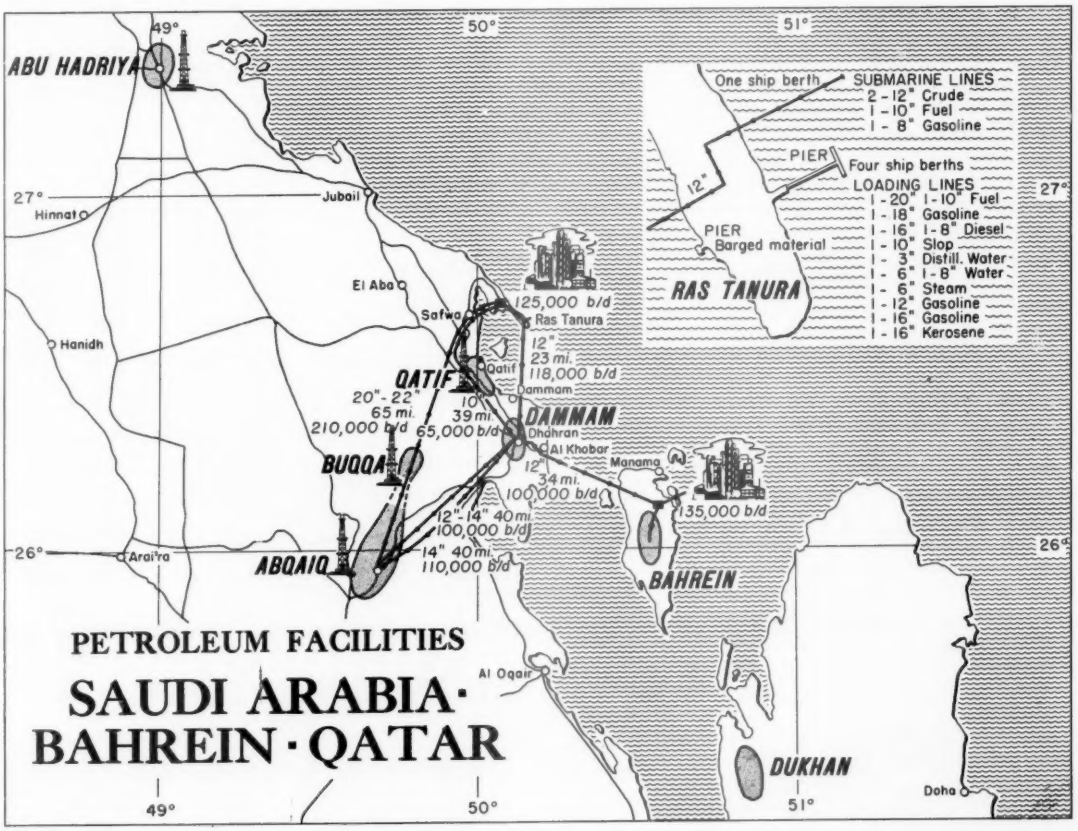
In Iraq, the British expected to build some tremendous dams and to irrigate from the Euphrates and Tigris Rivers. This project did not materialize, but small drilling outfits now are going into the Tigris and Euphrates Valleys and putting down shallow water wells. They get water immediately, and pump it with Diesel engines through small irrigation ditches.

REQUISITES TO ABUNDANCE

In many ways the Middle East is still living in the Eleventh Century. As a result of pouring hundreds of millions of dollars into the drilling of wells, the building of docks and refineries, the laying of pipe lines and the construction of whole communities, this area can be transformed into one of promise and its society into one of hope.

For each dollar now being spent in the Middle East for oil facilities, another dollar is being spent by the oil industry for those things which in America are supplied by the community.

Money, however, is only one requirement. No amount of money will long benefit the people themselves, unless they receive with it practical economic



and social guidance. And not least of all, they must see practical demonstration of the superior workability of our way of doing things.

Furthermore, neither money nor the teaching of American skills alone will assure productivity of the soil or abundance to the people. The governments figure importantly in this equation, as do the customs and laws of the ancient civilization by which the people live.

Nevertheless, all these tremendous investments in money, in time, and in examples of modern living should produce increasing results as time goes on. Once off dead center, an engine easily picks up speed and power.

SUMMARY

To summarize, then, in the development of the oil resources of the Middle East we have on the one hand the means of transforming an area of great and almost universal want into one of general prosperity and comfort. On another hand, we have the most feasible means of supplying the energy for that European economic recovery which, in turn, holds the key to world peace.

This is no snap job, financially or otherwise. The risks are great. But far greater are the results that can come from getting ahead with it.

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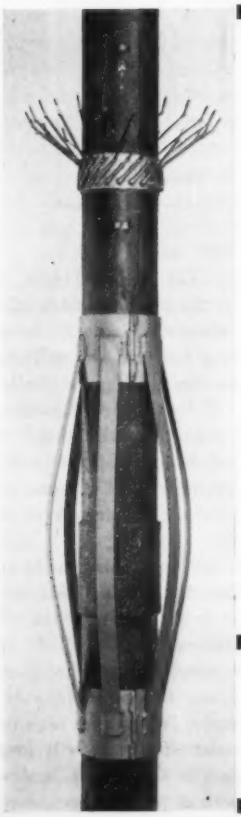

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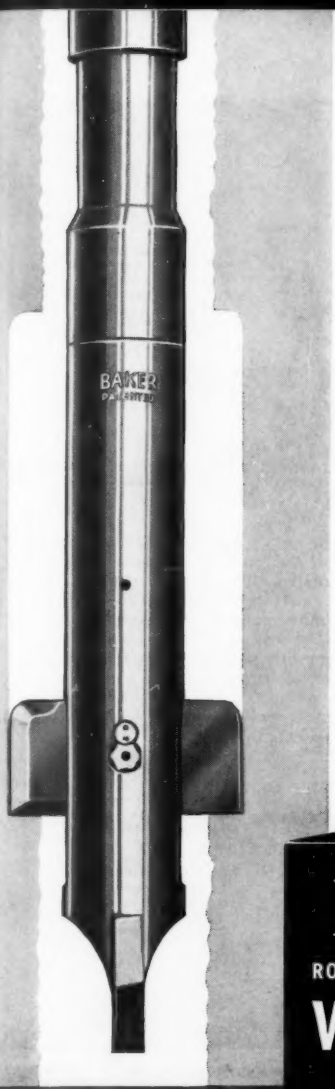

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RUGGED BLADES CLOSE SAFELY

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MANY IMPORTANT USES

THE BAKER ROTARY WALL SCRAPER is extremely versatile and is successfully and economically used for many worthwhile applications, a few of which are shown below. It will pay you to learn all about the Baker Rotary Wall Scraper (Product No. 500-D) from your BAKER (or Composite) CATALOG, or better yet, ask the Baker representative in your area for helpful suggestions as to how this efficient tool will fit right into your drilling program.

BAKER

ROTARY HYDRAULIC EXPANSION

WALL SCRAPER

PRODUCT NO. 500-D

Fig. 1

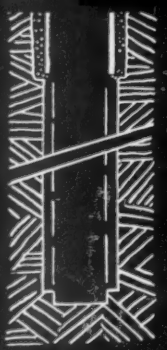
Fig. 2

Fig. 3

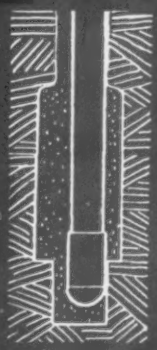
Fig. 4

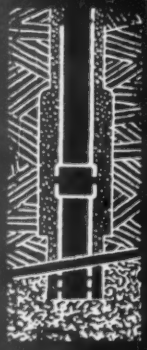
Fig. 5

Fig. 6

These typical uses illustrate a few of the many worthwhile applications of the Baker Rotary Wall Scraper.

Figure 1—WATER SHUT-OFF TESTS are made after rat-holing below the shoe, "wall scraping" for a vertical distance of 5 feet or more to the gauge of the original hole (or slightly beyond). Figure 2—ENLARGING HOLE TO SET CASING OR LINER with maximum ease and safety. Figure 3—REMOVING MUD SHEATH from the face of the formation to permit cement to bond with original formation. This same procedure is used to scrape the face of the oil sand to increase production. Figure 4—BOTTLENECKING to insure complete encasement of the shoe joint with cement; also to minimize hazard of channeling at this vital point. Figure 5—ENLARGING HOLE FOR C.P. JOB—showing "bottlenecked" section with casing or liner serving as water string above, and oil string below, the cementing point. Figure 6—GRAVEL PACKING is easily and effectively performed when the hole has been enlarged with a Baker Rotary Wall Scraper.

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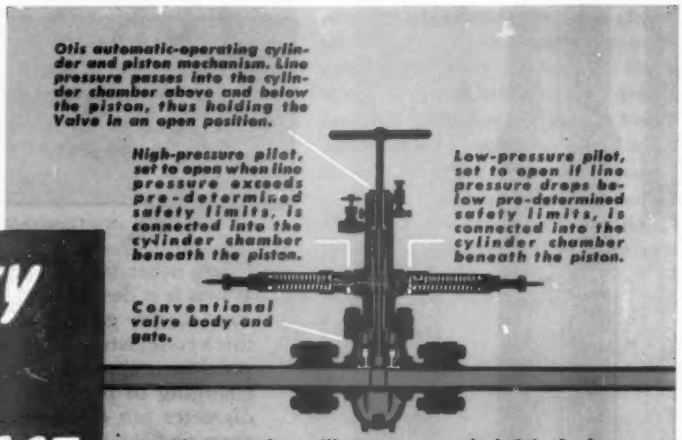
flow line SAFETY in a heavy-duty PACKAGE

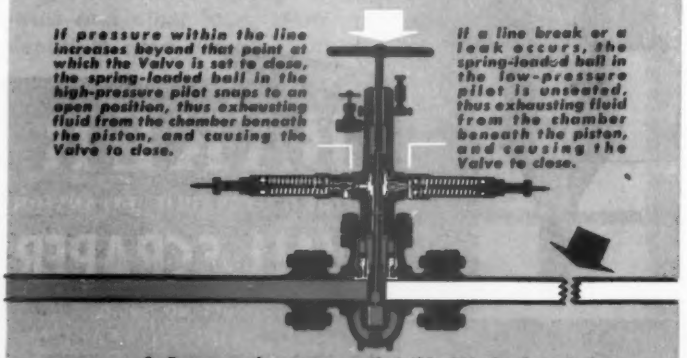
Otis Surface Safety Valves are full-opening pressure-operated gate valves which can be installed on single and two-zone well connections, flow lines, transmission lines, etc., to provide an automatic and positive shut-off when line pressure varies from predetermined high or low limits.

The Valves consist of an Otis Surface Safety Valve bonnet assembly (internal cylinder and piston arrangement) and either a high-pressure or low-pressure spring-loaded pilot valve, or both, combined with a conventional heavy-duty gate valve body and gate. The force which actuates the Valve may be supplied either by pressure from the line in which the Valve is installed, or by pressure from an outside source. The pilots are adjusted to open automatically when line pressure varies above or below an exact selected range. In either case, pilot action causes the piston to automatically drive the valve gate from a fully-opened position to positive shut-off — *the instant safety demands.* (For specific operating details, see diagrams on right.)

If your oil or gas lines are vulnerable to freeze-ups, breaks, leaks, or any other unpredictable condition which might cause pressure variations above or below safe limits, check with the Otis man nearest you. He is well-equipped with facts, figures, and case histories of numerous Otis Surface Safety Valve installations.


Otis automatic-operating cylinder and piston mechanism. Line pressure passes into the cylinder chamber above and below the piston, thus holding the Valve in an open position.
High-pressure pilot, set to open when line pressure exceeds pre-determined safety limits, is connected into the cylinder chamber beneath the piston.
Low-pressure pilot, set to open if line pressure drops below pre-determined safety limits, is connected into the cylinder chamber beneath the piston.
Conventional valve body and gate.

1. Diagram above illustrates a typical Otis Surface Safety Valve installation. The Valve is composed of a conventional valve body and gate; a bonnet and stem assembly incorporating the exclusive Otis cylinder-and-piston arrangement; and equipped with a high-pressure pilot (left) and a low-pressure pilot (right). These spring-loaded pilots are actuated, respectively, by an increase or decrease in pressure supplied by the line in which the Valve is installed. The complete Valve is self-contained and full-opening. (See Paragraph No. 2 below).


If pressure within the line increases beyond that point at which the Valve is set to close, the spring-loaded ball in the high-pressure pilot snaps to an open position, thus exhausting fluid from the chamber beneath the piston, and causing the Valve to close.
If a line break or a leak occurs, the spring-loaded ball in the low-pressure pilot is unseated, thus exhausting fluid from the chamber beneath the piston, and causing the Valve to close.

2. For example — presume that this Otis Surface Safety Valve is installed on the flow wing of a gas-distillate (corrosive) well which has a flowing pressure of 2100 p.s.i. The well, located in a river bed, is connected to a separator through approximately 200 yds. of exposed flow line, making the line vulnerable to flash floods and high water. The Otis Surface Safety Valve is operated by pressure from within the line. In case the line is broken and pressure drops below 1700 p.s.i. (that for which the low-pressure pilot is set) the low-pressure pilot is actuated, thus causing the gate valve to automatically close to a positive shut-off and remain closed until opened manually. Likewise, in the event the line is subjected to an increase in pressure above 2400 p.s.i., the high-pressure pilot is actuated and the Valve is instantly closed to prevent a line break.

PATENTS APPLIED FOR

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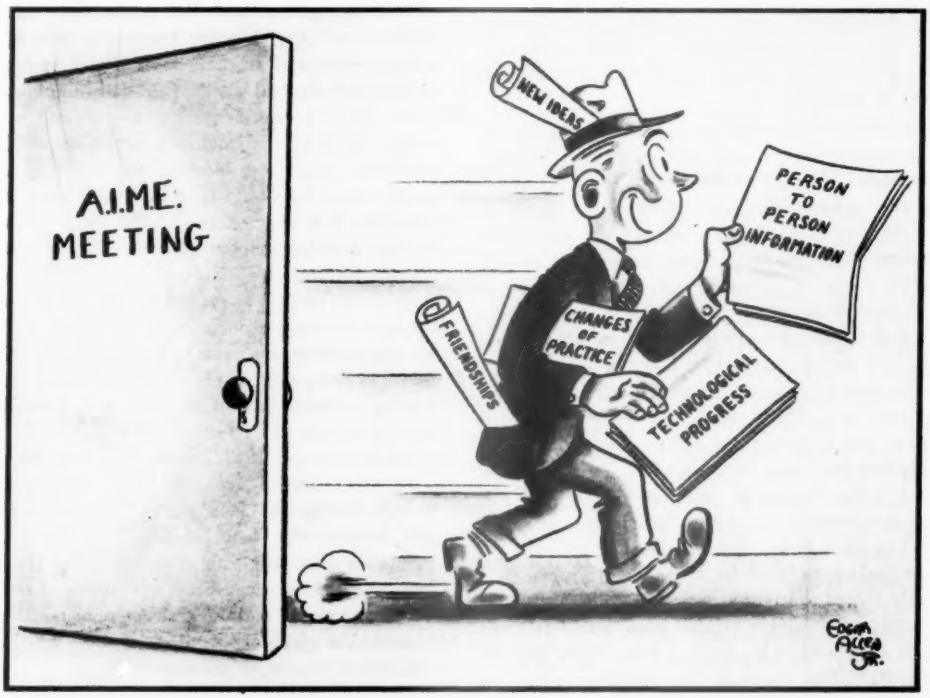


Getting Your Money's Worth

By E. H. ROSE • TENNESSEE COAL, IRON, AND RAILROAD CO., MEMBER, AIME

From the more distant members and some not so distant, the plaint is often heard that they cannot justify the expense and time required to attend the AIME Annual Meeting. Almost invariably, the reason given takes this form: "I just don't see that I would get enough out of it." Often the would-be clincher is added: "Besides, the meat of it all comes out in print anyway."

Not long ago, a group of us who have seldom missed a meeting in recent years fell to discussing this phenomenon, and found ourselves in emphatic agreement that anyone holding such a belief indicates by his first remark that he does not know how to attend a convention, and by his second, proves it. He is, by and large, the man who has never been there, and of him, there are many. Since he must often justify an expense account, these remarks are addressed to his employer as well, with the

behest that prospecting for new technological knowledge or advances is like prospecting for ore or oil: the reconnaissance crews have to get out and look methodically, and in the right places, which are not necessarily the "obvious" places.

This observer does not profess to be an expert in the matter, nor even a good journeyman instructor, but some compelling points may be ticked off by anyone who has had repeated exposure to the atmosphere of mining meetings.

(1) *Information picked up in person-to-person contacts bulks far larger in take-home payoff than the official fare.* The formal presentations necessarily are contributions to knowledge in the broad sense. They deal with the contributor's experience, not the listener's. They are a one-way conversation, so to speak. The listener takes no really active part, other than discussion from the floor and that only after the speaker has had his uninterrupted say. There is no give and take concurrent with the presentation, and afterward it is too late for the knocking about of points of detail, even if time permitted, which it never does, and even if the listeners did not self-consciously "freeze" as they attempt their remarks from the floor, which many of them do.

But in the corridors, it's different. There and in the uninhibited informality of private rooms, where kindred spirits foregather, you find the source of the kind of information you came to get—the details too small or specialized to come out in the necessarily condensed formal sessions, the latest on-the-scene accounts of experiments known to be in progress but not yet advanced enough for formal reporting, the stories of experiments that failed and hence were not published to warn others away from the same blind alley, and the innumerable straws in the wind to indicate the direction of technological progress to come. There you do not take larger topics, one at a time, and exhaust them before passing on to the next. There you really get down to cases. I tell you how I am trying to do something; you come right back and tell me how you learned to do it better and you make me a sketch. You have heard that the Doakes mill has recently done itself some good by a change of flowsheet; I have recently visited that mill and tell you about it, since it is not confidential, and a Doakes man would tell you himself if he happened to be about. I have heard that the Hoozit Manufacturing Company has recently come out with a new automatic control device; you tell me you have had one in your plant for several months and it's a honey. You have heard that my outfit is doing some work with this new method of roof pinning; that happens to be off my beat but I take you around and introduce you to a man who knows all about it, whereupon the cycle begins all over again.

Little stuff perhaps, but of good assay, and sometimes a real nugget turns up. If our friend in the first paragraph insists upon measuring dollars to the disregard of satisfactions, he might calculate that one little such item reduced to practice back home for a saving of a picayune twenty dollars a month would pay for his annual trip to the meeting, even if he came from the other side of the continent. The "regulars" know that Lloyd's would make a neat profit by writing insurance to that general effect. It is, indeed, the reason those fellows show up year after year—without insurance other than their own convictions built up out of experience.

Nor is it all little stuff. I can cite chapter and verse on two major changes of practice in large plants that came about five years sooner than they otherwise would have, as the result of just such conversations in the byways of Annual Meetings—and no confidence violated in the process. Indeed, it was discovered afterward that the basic data and interpretation pointing the way to one of them had been published as an AIME paper years before, without the potential beneficiaries reading themselves into the act.

(2) *Repeated attendance pays increasing dividends.* Implicit in the foregoing is acquaintance with those persons of the most relevant interests, and the degree of mutual benefit is measurable by the degree of mutual friendship, understanding, and respect. The standoffishness of strangers is fatal; the camaraderie of old friends, perhaps not seen since the preceding meeting, is the instantaneous catalyst that induces the real reaction of minds, and the real yield of profitable guidance on both sides. It is no accident that the mining profession is unique in being commonly referred to as the "mining fraternity" and every meeting attests the aptness of that designation. He would be a backward soul, indeed, who, after the first year or two, could come away from any Annual Meeting without at least a dozen new first-name friends, to push his circle of provincialism correspondingly outward. (It is superfluous to ask if our Doubting Thomas averages a dozen new friends a year in his field by any other means open to him, unless it be by endless travel.) Attending regularly, his contacts, instead of becoming so broad he cannot cope with them, become the more selective and fruitful. An enlightening illustration came out of the 1947 Denver Regional Meeting, when Jack Myers and I exchanged our company reports on that gathering. As Jack put it, "You wouldn't think we had been at the same meeting," for the problems and points we discussed with others were not the same problems and points, because the operations of our respective personal concern and our sources were not the same, and likewise the gleanings we deemed most worthy of reporting to our respective managements.

(3) *Reciprocity is essential.* In addition to attendance, participation in Institute activities is the key that opens the door to the benefits sought. On that point, I can speak with authority, having been an Institute member for twelve years before attending my first meeting and sixteen before serving on a committee, but thereafter diving in enthusiastically. I can correspondingly understand the mental colic of the mail-order-minded member who sends in his annual dues and expects merchandise of said value to return to him at stated intervals. The poor fellow has his frustrations coming to him, but little sympathy. He's the chap who bought a bicycle but never learned to ride it, then complains that it doesn't take him anywhere. He has never really appraised the three points made herein, or if he has appraised them, has done so

under the handicap of not recognizing the Golden Rule, in professional society affairs, as not a rule at all but an automatic proportionality, truly though tritely expressed as, "You get out what you put in." The principle is that of trade; it is as simple as that.

Many inactive members sincerely believe that they are not qualified to write papers, for lack of either material or talent. Often, that may, indeed, be true, but it does not follow that they are unqualified to pursue other activities, such as serving on national or Local Section committees, all of which is as voluntary as the writing of papers and even more rewarding. Someone may say that he has never been "put" on a committee. The process is not quite so passive; one has first to open his eyes to the many ways in which he could be useful to others and thus in due process to himself and to his employer. To be selected, he must become visible. A few thoughtful letters written to the chairmen of committees covering his field of work or his geographic area—making suggestions, offering criticisms, or even merely asking the questions he asks himself verbally—and he will soon find himself out on the main line moving with traffic. He can be perfectly selfish about it, not for a moment pretending that such activity on his part is out of the kindness of his heart or for love of his fellow man, but strictly on the basis that such is directly or indirectly a sound currency of trade for any of the several desirable objectives: professional recognition, technological information, a promotion, or a different job. It just happens to work that way, as many can attest. Even on a committee, there will be no one standing at his elbow telling him what to do. It is his in-time-well-rewarded job to think of something to do, just as in the conversations stressed under point (1) he must contribute information as well as seek it.

And so, the question "how to attend an AIME meeting" or even "how to be an AIME member" boils down to one simple principle: "Give and ye shall receive." The mechanics of doing so presume a smattering of originality and extraversion, but beyond that one could more simply convey the idea by defining how *not* to attend an AIME meeting: don't just sit still and wait for the manna to rain down. You will be disappointed if you do.

Engineering Societies Library Reports

Library costs have risen more than Library income but not as much as the cost of living. The net result of this is that the Library can purchase relatively fewer books and magazines, and the staff has relatively lower income. By placing greater emphasis on paid services and by increasing the rates for services, the percentage of income from services has been doubled since 1939.

Pending funds from the Engineering Foundation, a survey to reorient the ESL with other technological libraries in the country is to be made. It is also planned to try to obtain support from industry.

Use of the Library has leveled off this year after a spurt in the two preceding years that had raised Library use more than 20 per cent. The statistics of Library use are:

	1946-47	1947-48
Visitors served	23,557	22,228
Nonvisitors served	17,098	17,442
Total	40,655	39,670
Photostat orders	4,392	4,135
Photostat prints	53,597	49,954
Microfilm orders	114	141
Searches	140	141
Translations	45	49
Words translated	136,192	212,288
Borrowers	1,835	2,200
Books loaned	2,628	3,011
Telephone inquiries	7,358	7,263
Letters written (exclusive of book orders)	3,214	3,513

A series of bibliographies has been initiated. These are intended for general distribution and they will be sold at prices that will at least cover their cost. The first is entitled "Filing Systems for Engineering Offices." Others in the series will cover various engineering topics of current and general interest in all fields of engineering.

Some persons who come to the Library have little or no knowledge of English but current members of the ESL staff can converse fluently with these persons in French, German, or Russian and with some difficulty in six other languages. Among the translators that are subject to call are persons who can translate almost any foreign language into English.

As in the past, the Library has received many valuable gifts of books and magazines. There were no outstanding gifts during the year, but some of the larger and more useful ones were those from the following: D. W. Barron, A. Eckwall, S. W. Farnsworth, M. Pirnie, B. W. Shaffer, and F. T. Sisco. Various technical societies, publishers, and other organizations have given generously of their own publications and other publications that have come to them. The Library has been enriched by the many gifts received. Sincere thanks are extended to all donors. It now contains 166,470 volumes, 10,514 maps, and 5056 searches, a total of 182,040 items. —*Ralph H. Phelps, Director.*

Pittsburgh Off-the-Record Meeting

Under the direction of R. F. Miller, of Carnegie-Illinois Steel Corp., and C. R. Fitterer, University of Pittsburgh, a most interesting program was arranged for the Nov. 12 all-day meeting of the Pittsburgh Section. It was attended by approximately 680 persons, of which 135 were students representing the University of Pittsburgh, Carnegie Institute of Technology, University of West Virginia, and Pennsylvania State College. Since the program was off the record, no attempt was made to make notes of the remarks of the individual discussers, but each session was interesting and educational, with good discussion of the papers. The National Open Hearth Committee held the largest number of sessions but the Coal Division, Institute of Metals, and Petroleum Division also held important meetings.

The meeting was concluded with a cocktail party through the courtesy of the suppliers' group of the Pittsburgh area under the chairmanship of R. S. Runyon and a dinner at which J. E. Thornton, special agent in charge of the Pittsburgh Office of the FBI, gave an interesting talk on his personal experiences as an FBI agent.—*Hugo E. Johnson.*

LEWIS EMANUEL YOUNG

President, AIME, 1949

Lewis E. Young, who will formally assume his duties as President of the AIME at the Annual Meeting in San Francisco in February 1949, was born in Topeka, Kansas, Oct. 1, 1878. Dr. Young received his engineering education at the Pennsylvania State College, where he received the degree of B.S. in Mining Engineering in 1900. In 1904 he received his E.M. degree from Iowa State College, and in 1915 a Ph.D. from the University of Illinois. In 1947, the University of Missouri conferred on Dr. Young *honoris causa* the degree of Doctor of Engineering.

His active career began in the educational field as instructor at Iowa State College, and following that, as professor of mining at the Colorado School of Mines, 1903-1907. While he was at Golden he launched his career as consulting mining engineer for various Western companies.

Leaving the Colorado School of Mines, Dr. Young returned to Missouri, serving the University of Missouri as director of the School of Mines and Metallurgy at Rolla, 1907-1914. Leaving Missouri he went to the University of Illinois as assistant professor of business organization, 1915-1918, during which period he wrote exhaustive treatises on mine subsidence and mine taxation, which won for him the degree of Ph.D. before mentioned.

With World War I confronting the nation, Dr. Young plunged into production work, becoming manager of the steam heating department of the Union Electric Co., of St. Louis, 1918-1922. With the completion of the Company's steam heating expansion program, Union Electric called on Dr. Young to fill the position of general manager of the Union Colliery Co., a wholly-owned subsidiary, where, for four years, 1922-1926, he pursued a program of complete mechanization of the Colliery Company's Kathleen mine, in Jackson County, Illinois.

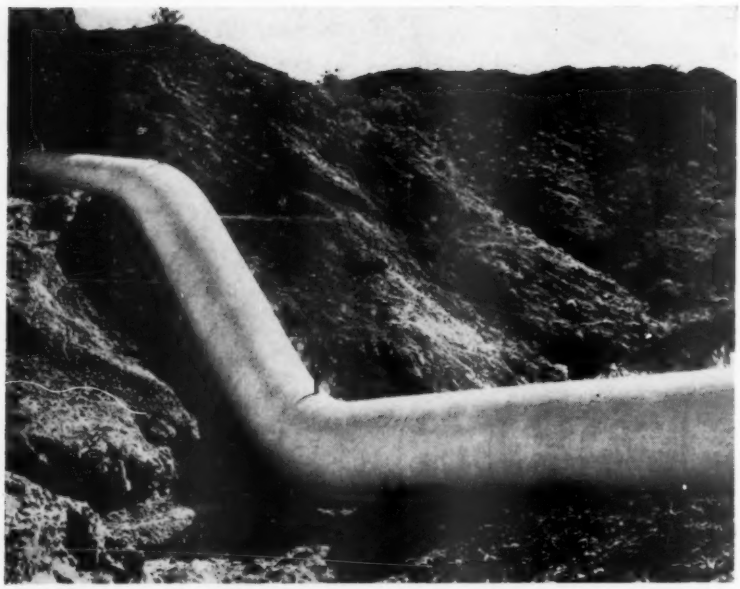
With that task behind him, Dr. Young was offered the vice-presidency of the Pittsburgh Coal Co., which, subsequently combined with Consolidation Coal Co. and a number of lesser properties, became the Pittsburgh Consolidation Coal Co., the largest producer of bituminous coal in the world.

Dr. Young, never static, after resigning from the Pittsburgh Coal Co. in 1939, decided to go on his own, opening an office in the Oliver Building, Pittsburgh. Since then he has roamed, not only the United States, but in addition, Canada, the British Isles, France, Germany, and more recently South America, aiding and encouraging his many clients in the development of coal and nonferrous mineral properties, giving particular attention to mechanization, preparation, and cost reduction. Those who know Dr. Young best do not hesitate to say that his knowledge of mechanical mining methods is on a par with that of the top men in that field.

Dynamic in movement and speech, our friend will go anywhere, by air, land, or sea. Those who have followed the tall, rangy, one-time prof below the surface, in thin and steeply pitching seams, wonder how he keeps up his speed. No one would ever guess his age as seventy. Nowhere is he so happy as when addressing a body of young engineers, who invariably leave him with an added conception of the opportunities and responsibilities of the mining engineer. All over the United States, the one-time boys who sat in front of him in Penn State, Iowa State, Golden, Urbana, and Rolla, who are now mature men, invariably greet him effusively and affectionately, the conversation harking back to that most interesting of periods, their school days.

Through his busy career, Dr. Young has found time for writing numerous technical papers for this and other technical societies and engineering periodicals. Like practically all of the men who have achieved especial prominence in the mineral industry field, Dr. Young joined his professional society early—in 1901, the year after he graduated from Penn State. Elected a Director in 1937, he served three terms on the Board and was Vice-President from 1942 to 1945.

Dr. Young has one son, Edwin W. Young, engaged in newspaper work in the Middle West. Dr. and Mrs. Young make their home in Pittsburgh.—*E. M.*



Water, an industrial mineral, doesn't go to market in freight cars but moves in giant conduits. Here is a steel-reinforced concrete inverted siphon, 16 ft in diameter.

Water—

Industrialization is raising the standard of living of people everywhere. The common man is demanding and getting more of everything. Perhaps more markedly than most other things, he is consuming more water. A hundred years ago water for domestic use, in all but a few large centers, was lugged from wells in buckets. This still is true in many rural areas, even in the enlightened United States of America, but pumps and pressure systems are rapidly replacing the "old oaken bucket," even on farms and in isolated country homes. Nevertheless, many still fail to see water as a "commodity," in the same sense that coal, lumber, fertilizer, and bread are considered as commodities. Water is too frequently taken for granted.

If a mining man needs more air for a shaft or adit, he simply installs another blower and takes it from the conveniently adjacent atmosphere. The industrialist, needing more air for a factory or building, does the same thing. The availability of an inexhaustible supply of air for such uses is fortunate. It also would be fortunate if other elements essential to human activities were equally available, but, of course, they are not. Food, clothing,

A paper presented before the Industrial Minerals Division, AIME, at the Oct. 24 meeting in Los Angeles.

Transporting water by canal is one way to get it there. There are 63 miles of concrete-lined open canals in the 242-mile main aqueduct system which carries water from Lake Havasu to three million inhabitants of Southern California.

Lowest Cost Industrial Mineral

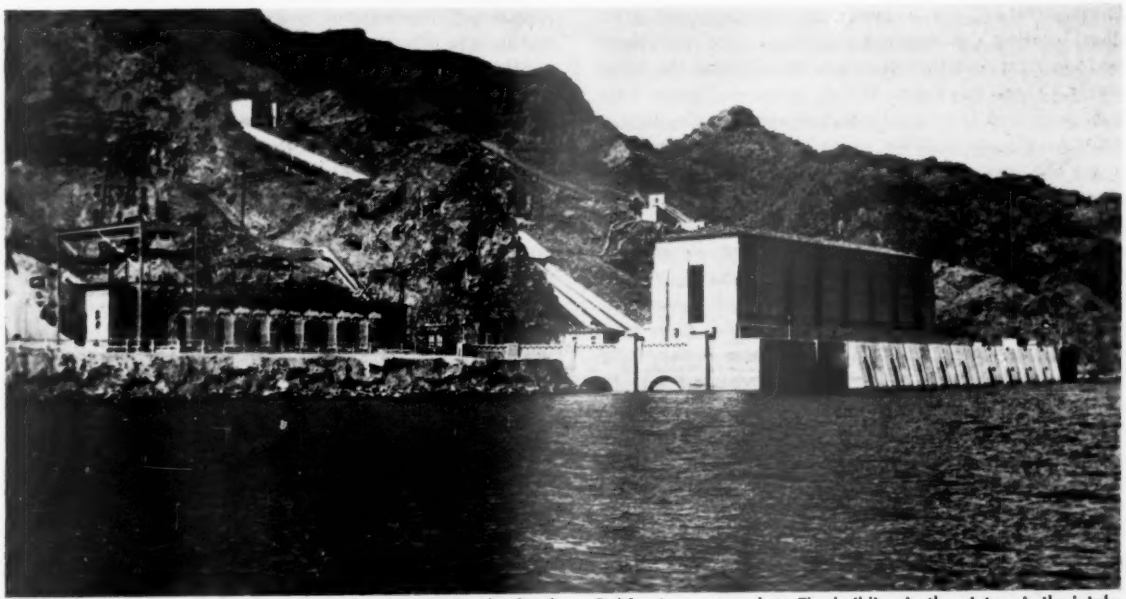
By **JULIAN HINDS** • GENERAL MANAGER, METROPOLITAN WATER DISTRICT, LOS ANGELES

shelter, and the thousand and one things required to meet modern needs are obtainable only at the expense of exertion.

There was a time when water for most people and for most purposes was almost as abundant as air. Our not too distant ancestors, thinly scattered over humid areas or grouped in small numbers about oases, gave little thought to water as a problem—except in times of unusual drought. If more water was needed, another bucket was sent to the spring or stream, or another shallow well was dug. Increasing numbers and the spreading of populations into arid regions have changed this. Water has become one of the elements that must be striven for.

This change has come about so gradually that the average man on the street is not too painfully aware of it. The city dweller thinks of water as something that comes out of faucets. If he wants more water, he buys another faucet, little aware of the effort often required to find the water, refine it, and pipe it to his outlet. Ordinarily, this is as it should be. Production is left to experts, just as the production of coal or copper is left to the expert miner and metallurgist.

At times, however, the consumer needs to give serious thought to the nature and adequacy of the source of his



Lake Havasu reservoir is a stock pile of water for the Southern California area market. The building in the picture is the intake pumping station which starts the water on its way over the longest man-made aqueduct system in the world.

Hoover Dam, keystone of the Colorado River aqueduct development program, measures 727 ft from foundation to crest.

water. This applies to the home owner as well as the miner about to open a milling plant in an arid region. It applies particularly to those proposing to initiate water-consuming industrial enterprises.

Unfortunately, water is all too frequently the last thing a promoter thinks of. This was particularly true during the war. Factories and housing projects were built with great abandon on flat spots that could be bought cheaply, only to discover too late that the site was cheap because it had no water.

The same thing can happen in peacetime. As a recent example, the promoter of a postwar cement project in southern California acquired suitable deposits in the desert, arranged for a power supply, expended great effort locating the required machinery, and was about ready to start construction before investigating the water supply. There was none. Mining ventures likewise have been developed and abandoned because of inadequacy of water supply—a condition which should have been foreseen. The same careful advance consideration should be given to water as is given to power, raw materials, and other essentials.

The water system built along the Colorado River aqueduct of the Metropolitan Water District, to supply water for construction purposes, affords a good example of water planning for a specific enterprise. This great waterway was to be built 250 miles across a desert, devoid for much of this distance of any visible water for the maintenance of life or for construction purposes. Careful reconnaissance indicated the possible presence of underground bodies of water in rather widely separated desert basins; many were salty, but usable supplies were found at forty- to fifty-mile intervals. Obviously, it would have been uneconomical to require each individual contractor to transport water over such distances. Consequently, as a preconstruction enterprise, the District developed all of these sources, provided pumps and storage reservoirs, and laid a construction water line for the full length of the project. Fifteen usable wells, varying from 16 to 785 ft in depth, were drilled in half a dozen locations. There were also a number of salt wells and "dusters." The supply line consisted of 180 miles of 5-, 6-, and 8-in. diameter lightweight, continuously-welded steel pipe, laid in shallow trenches. The total cost of the system was $847,000 and it was much more than worth it. The supply was adequate.

Such elaborate planning of a water supply for an individual project is, of course, unusual. Most large enterprises can tap some community water system. Before risking any great investment, however, both source of supply and adequacy of delivery system should be investigated.

Most water-supply systems have grown more or less piecemeal, starting with a few families and expanding by various expedients with the growing population, systematic planning being introduced at some later date to avoid an impending disaster. In this way, the great modern water developments of the world have grown.

A most interesting example is found in the development of water in southern California. The white man found this an arid region, an excellent place for a few people to live, but subject to severe and prolonged droughts. During wet periods there were lush pastures, springs, and flowing streams, encouraging increased development, expansion of herds, and the introduction of irrigation. Then came drought. Irrigation ditches ran dry, cattle died, and people moved away. But in spite of these periods of discouragement, there was some permanent development. The climate was good, soil fertile, and all kinds of fruits and crops flourished wherever and whenever there was water.

Ground water as a source of irrigation supply was not at first taken seriously, but wells were, of course, resorted to for domestic supplies, and at times of drought for

watering livestock and perhaps for home gardens. The early dug wells merely tapped shallow surface sources, but finally, with the introduction of the drilled well, someone pierced the clay cap and struck a gusher—a bountiful artesian flow. The boom was on! Here were vast expanses of wonderfully fertile lands, with a bountiful water supply just a few hundred dollars beneath the surface. Development went forward at a stupendous rate. Nobody asked where the water came from, how much there was, or how long it would last. There was no organization to ask such questions and the individual farmer was too busy to ask anything. The supply was looked upon as inexhaustible, and wells multiplied.

Soon outflow began to exceed replenishment. Pressures dropped and wells ceased to flow. But the farmers, now grown wealthy, were loath to walk off and leave their homesteads. Furthermore, they could now afford to pay for water—they could afford to pump it. And so pumps went down as fast as artesian flows stopped. And more pumping wells were drilled, still with the feeling that there were great underground oceans of fresh water, to all intents and purposes inexhaustible. And thus began one of the most stupendous mining operations of all time.

As geologists later explained, there actually was a vast, though not inexhaustible, underground storehouse of water. Practically the entire coastal basin is deeply underlain with porous detrital fills, covered with a blanket of topsoil and clay of varying thickness. Each year a small portion of the sparse rainfall and meager mountain runoff around the upper perimeter of the basin sinks into the ground. During prehistoric ages these small percolations completely filled the underlying strata and welled up against the clay cap covering the lower portions, creating an artesian pressure. It was thus revealed that the early settler's herds had died of thirst on the roof of an enormous lake of good water.

But it was only a lake and not an inexhaustible sea of fresh water, as many wishfully believed. With increased pumping, water levels sank and many wells went dry, or lowered levels permitted sea water to flow landward, contaminating the source of supply. Ultimate exhaustion became obvious, but abandonment was by now out of the question. Experts were employed and the problem was studied from all its angles. Steps were taken looking toward complete conservation of all flood waters formerly wasting into the ocean. Spreading works were constructed to encourage percolation into the underground basin, and surface storage was created where possible.

But these measures were inadequate. An annual rainfall of 15 in., no matter how thoroughly it is conserved, cannot support a semitropical civilization. Importation of water was obviously essential. There is no long river bringing water in naturally from distant sources, and near-by surrounding territory is true desert, producing no worth-while runoff. So, early in the present century it became evident that an artificial waterway to some distant point must be constructed. As a result, the then small City of Los Angeles voted the stupendous sum of $23,000,000 to build an aqueduct to tap the Owens River, 250 miles to the north. This river collects the drainage from the precipitous eastern slopes of Mt. Whitney and other snow-capped mountain peaks of the High Sierras.

Setting steel to reinforce concrete in a 16-ft high conduit.

The aqueduct was completed in 1913 with a capacity of 450 cfs. It was expected to end the water needs of Los Angeles for all time. But just as the discovery of artesian flow engendered overdevelopment, so did the introduction of Owens River water. The inexhaustible idea was again rampant, and the city began doubling in population every ten years. Leaders soon saw that the battle for water had just begun and eyes were turned to the only other adequate source—the Colorado River—frequently referred to as "the last water hole of the Southwest."

Water from the Colorado River for the coastal areas of southern California could be obtained only from the flood flows. Normal low flows were already completely appropriated. The creation of storage on the main river was not a job for a single community. The stream is interstate (in fact, international), floods are great, and silt is a problem. The political situation was complex. But the problem was courageously attacked and solved.

The amount of work involved has been prodigious. Interstate compacts, enabling acts in Sacramento and Washington, and contracts and agreements on a national scale consumed unimaginable time and effort. Finally, construction of Hoover Dam by the U. S. Bureau of Reclamation was authorized. The Metropolitan Water District, comprising the principal cities of the South Coastal Plain, was organized, and $220,000,000 worth of bonds was voted to build an aqueduct to bring more than one million acre feet per year of the conserved water to the needy coastal communities. The job was started in the bottom of the depression and finished just before the beginning of the war, substantially under the original estimate of cost.

This aqueduct again was expected permanently to end the water worries of southern California. It is now evident that this is not the case. The necessity for some

Barring down after the blast which holed through the San Jacinto tunnel. This tunnel pierced 13.04 miles of solid rock in the San Jacinto mountain range and was the most difficult unit of the entire metropolitan aqueduct construction.

limitation of ultimate development is likely unless an additional source beyond "the last water hole" is found and tapped.

This story illustrates the effort involved in planning for a water supply. Most systems are, of course, smaller and simpler. Many of them have been planned with relatively as much care as that described, but usually with less elaborateness. Many small municipal and private systems are still going largely on faith and although usually adequate for ordinary needs, cannot stand a sudden expansion of demand. A prospective investor should carefully check the adequacy of such supplies.

Reference has been made to the extraction of ground waters in the southern California coastal area as a mining operation. Water being a mineral, this reference is perhaps justified by the dictionary definition of mining. The primary distinction between water mining and the mining of other minerals is that water is sometimes replenished by percolating rainfall, permitting the continued repetition of the mining operation. In the Los Angeles coastal area this was only partly true. In fact, the foundation of the present great civilization in this region was built on fossil waters, accumulated through countless prehistoric ages. These basins never again will be fully filled, and the "take" must now be limited to the annual crop. Nevertheless, the beneficial effect of the fossil waters was great. The artesian wells produced the wealth that could afford to pump; the pumped wells produced the wealth that could afford to build the Owens River aqueduct; and the supply from this source produced the wealth required to go to the Colorado River. If any of these links had been missing, the chain could not have been forged.

Production of water by mining operations is, of course, not limited to southern California. Well waters are used throughout the world for individual supplies, municipal supplies, and irrigation. Production is often deliberately undertaken on a pure mining basis, with no hope or expectation of replenishment. Desert lands underlain by nonreplenishing water bodies have been hurriedly put into cotton or other temporarily high-priced crops, with the hope of a quick return, and with the expectations of abandonment after a few years, but such operations are likely to be detrimental to adjacent lands depending on a perennial underground water crop.

Water, like other mineral products, must be transported to its points of use after it is "mined." Sometimes it also must be refined—that is, softened or otherwise purified. In contrast to most commodities, water is delivered right where it is wanted, as wanted. It is not necessary to go to the railway station, warehouse, or store, and haul it home; or to wheelbarrow it in from the front yard. Its delivery is complete and the price of delivery is ridiculously low.

When the Colorado River aqueduct shall have reached full development, it will be capable of transporting 1 2/3 billion tons of water per year from 300 to 400 miles, lifting it through a height of over 1600 ft, and delivering it wholesale into the water systems of the coastal area at a cost slightly over one cent per ton, including interest on investment, depreciation, power for pumping, and all operation and maintenance costs. Refining (softening and filtration) will add another half cent per ton to the wholesale price. The retail price of water for household use in southern California will average about five cents a ton, delivered into the sink or bathtub, as and when needed. Irrigation and industrial water is much cheaper.

Thus the water producer sets a standard of economy which other producers and shippers will find it hard to approach—not because the water man's problems are easier, but because conditions favor low-cost production and because the volumes handled are so enormous.

JOHN FLICKINGER MYERS

Chairman, Minerals Beneficiation Division, AIME

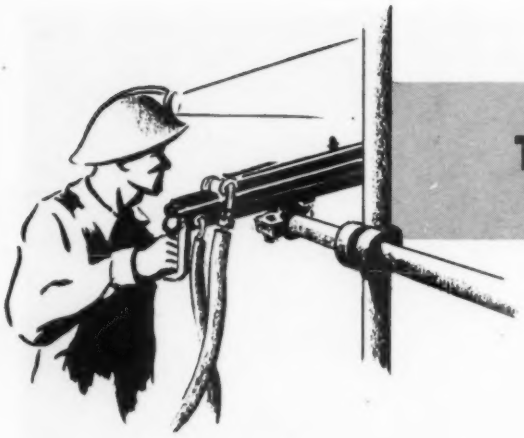
In Emporia or Claremore, time was when a path was beaten to the door of the local sage. Nowadays, the beginnings of such a path are discernible in Tennessee, as folks of the metallurgical persuasion find it to their pleasure and profit to call upon the Sage of Copperhill. They come, more and more respectfully as the years go by, yet to ever fewer persons is he known as Mr. Myers, but to more, eloquently, as Jack. Find better ways to run your mill, find happier means of co-ordinating your humanities or serving your professional society, and it's just like the man said about the mousetrap.

A druggist's son, born in Wisconsin, May 24, 1889, reared on the Bible in Ohio and Indiana, and completing his education in Colorado, this now indisputably 24-carat Tennesseean has had a checkered career. Going West as a laborer at the tail end of the 1907 panic, he did not make his fortune but he did gain an understanding of labor that in later years endeared him to his men. Graduating in 1913 from Colorado School of Mines with the degree of E. Met. and a string of football letters (also earned the hard way, at tackle) he went to work in Butte & Superior, just at the beginning of the Golden Age of flotation.

A year later, Jack is starting up the flotation plant of American Zinc at Mascot, Tenn., and putting an item into the textbooks, to wit, that copper sulphate is vital to the flotation of zinc sulphides. A year after that, now with New Jersey Zinc at Austinville and Canon City, he rounds out this discovery with first-order pioneering in alkaline circuits, and a patent or two. It was in 1926 that he joined Tennessee Copper to begin a dogged uphill fight to attain the frankly unattainable, such as a premium iron sinter from a three-metal *sulphide* ore, meaning a sinter containing less than 0.10 per cent copper or zinc. That takes some doing.

In a small operation in a little town, Jack has won international recognition. The credit he gives to others, with such compelling plausibility that maybe we shouldn't go into that. First, there's Billie, the girl he met in Butte, married in 1915, and has stayed married to ever since. Whatever their other doubts, those who know Billie concede that Jack showed early intelligence. (They have one son, Lorrin, who is now bouncing upward in NBC in a curiously reminiscent pattern.) Second, there's the AIME. Jack says—and so help me, he can prove it!—"Ninety per cent of our success here has come from AIME contacts. Sometimes I am ashamed of how little we ourselves have done and how much other folks have helped us."

We can't rightly say how much of that last is accuracy and how much is modesty, but whatever the ratio they add up to a humility the rest of us could do with a lot more of.—*E. H. R.*



THE DRIFT OF THINGS

. . . as followed by EDWARD H. ROBIE

A Fourth Round?

Talk is increasing about another round of wage increases—the fourth round. True, the cost of living has risen by some 7 per cent during the last year, so on this basis some further wage increase can be considered justified. But the rising cost of living shows some signs of tapering off; in fact, for the last month reported, it did drop off by a fraction of a point, the first time this has occurred. If this means that the advance has been stopped, then it is to be hoped that further wage increases can be held in abeyance, for experience has established the fact that a national round of wage increases causes a rise in the cost of purchased goods and services in an equal or even greater dollar amount than the increase in employment costs. However, the labor unions argue that, in the words of Gershwin's song, this "ain't necessarily so" —that the increase should come out of swollen profits.

Mr. Holman on Petroleum Trends

One product of the mineral industry that seems to be in increasing demand every year is petroleum. Even the excessive wartime demand was exceeded in the first year after hostilities ceased and the consumption has set new records every year since. Unlike many of the metals, however, petroleum has always been found in peacetime in sufficient quantity to meet all demands. As to the future, some have questioned whether we can count on the necessary increase in United States output or imports, and feel that some reliance will have to be placed on synthetic production from natural gas, oil shale, or coal.

In a talk before the Texas Mid-Continent Oil and Gas Association recently, Eugene Holman suggested that we could not count on the Middle East for a part of our oil except as a temporary measure, adducing two main reasons: first, Europe will soon be able to absorb all of the Middle Eastern production, when the necessary refineries are built; and second, for American capital, the cost and risk of development so far away are too high and the distance to market in this country too far, with import duties also to be paid.

One way that Mr. Holman thinks the problem of balanced supply and demand can be met is by improving the efficiency of oil-consuming equipment. He cites the Diesel locomotive as the outstanding example at present, for it will do the work of the oil-fired steam locomotive with about one fifth of the oil. Also, we may look for greatly increased automobile engine efficiency, and as gasoline for motor vehicles accounts for some 41 per cent of our petroleum consumption, any appreciable increase in efficiency here means much. Another economy will be found in the increasing ability of refineries to make gasoline and Diesel oil out of residual oil that was formerly burned, which can be displaced by coal, natural gas, or imported residual fuel. Presumably, therefore, fuel oil may become relatively more expensive than gasoline or Diesel fuel.

Annual Reports

Each year recently we have noted an increased tendency for mining companies, particularly those that have a product to sell to the general public, to issue fancy annual reports, printed in several colors on slick paper with plenty of photographs and art work. These are nice to look at but whether or not the companies get their money's worth out of them is questionable. Is this fancy presentation what the stockholders want?

Elmo Roper, while his reputation was still good, recently conducted an exhaustive survey for the Controllership Foundation (1 E. 42d St., New York City 17) which has published his findings in a pamphlet under the title "What People Want to Know About Your Company." It discloses that the average stockholder has little interest in corporate financial data, and uses other means of keeping track of his investment and deciding when to buy or sell. Some forty per cent of "run-of-mine" stockholders said they found no utility in the annual brochures they received. They want to know what the chances are that the company will safeguard its capital and pay the same or bigger dividends and they would appreciate a little discussion along this line. Only big investors want financial details, and they want much more than is given in the usual report.

So the Foundation recommends a brief statement, to go to all stockholders, outlining earnings, dividends, and the general financial position and outlook of the company, and offering a complete report on request. The latter would be a full-scale annual report designed primarily as a source document for those who wish ready access

to cold statistical facts. Employees would also like the brief digest.

The above applies to companies in general—not specifically to mining, metallurgical, or oil companies. For companies in the mineral industries field, we think AIME members would like to read in addition a statement every year (maybe 2000 words for the big companies, ranging down to a few hundred for the smaller companies) outlining the properties worked, new methods and equipment used, ore reserves, grades, recoveries, costs so far as can be divulged, results of exploration and development, new products and markets, labor conditions, names of operating officials, and a few other data of this general nature. But stockholders would not be so much interested as professional men, so we suggest that a brief annual report giving this information be offered for publication in the journals serving the industry.

News From the AEC

Not a great deal of news regarding its raw material supply emanates from the Atomic Energy Commission, but there seems no reason to doubt that most of the domestic supply of uranium ore continues to come from western Colorado, with that area also affording most promise for the future. Thus one of the oldest settled areas of the country, which was inhabited fifteen hundred years or more ago by the cliff dwellers, affords the newest of man's vital minerals. Within the last two or three months, arrangements have been made to facilitate the treatment of uranium ores offered by the individual prospector and operator. The U. S. Vanadium Corp. (Carbide and Carbon subsidiary) has agreed to purchase from independent miners, for treatment at its plant at Rifle, Colo., 63 miles northeast of Grand Junction, any ores adaptable to the process used there. Formerly, only company ore was treated. This will afford a market for ore mined in the northern part of the Colorado plateau and eastern Utah, and it is thought the plant may now operate at twice the scale that it has heretofore.

Another item of news has to do with southwestern Colorado, where the Vanadium Corporation of America is to take over and rehabilitate, at a cost of some $200,000, the vanadium-uranium mill owned by the Atomic Energy Commission at Durango, and formerly owned by the U. S. Vanadium Corp. Some of the ore supply for this mill, which is expected to go into operation later this year, will come from Navajo Indian lands, for which the Indians will receive a royalty. As at the Rifle plant, ore will be received from independent miners.

Vanadium Corporation also plans to erect a pilot plant in the White Canyon district of San Juan County, Utah, which heretofore has not been a producer but which has small, flat lenticular deposits of copper-uranium minerals. The mineralization extends across the line into Arizona, and prospecting should be stimulated.

These plants should do much to dissipate the dissatisfaction that many independent operators have voiced in the past concerning a satisfactory market for their product. The price they will get, however, is not a matter of bargaining between the miner and smelter, as for base-metal ores: it is set by the AEC, presumably at a level which they think will provide a reasonably adequate supply.

Many inquiries are also reported by the AEC regarding the possible value of thorium as raw material for nuclear fission. Monazite ore is the principal source of thorium, but there is little encouragement at present for producers of that mineral. Uranium 233 can be derived from thorium in a way similar to that in which plutonium is derived from uranium, and uranium 233, of course, is a desired fissionable material. However, complex research problems remain to be solved for the large-scale utilization of thorium in this way. Maybe in ten years or so monazite will be a raw material for nuclear energy, but not now. But until then, it remains the only known source of cerium and some other rare-earth metals which have varied, even though not extensive, uses.

And monzonite, if some prospector asks, is as worthless as ever.

Then and Now

When we were a little boy the first real engineering job that we had assigned to us was the operation of a small wood-fired boiler supplying steam to a pump that forced water uphill to a tank a few hundred yards away for irrigation in an orange grove. Our principal job was to keep the steam pressure up to at least 60 lb and to whistle for help when the water got near the bottom of the gage glass, for we were not quite equal to manipulating the injector or "inspirator" as it was called. Occasionally a bad and bigger boy would scare the daylights out of us by coming around, tying the safety valve down, and running the steam pressure up to about 90 lb, which we thought likely to blow the whole place, including us, to smithereens.

Our mind ran back to these early days when we read the other day of a new Westinghouse 100,000-kw turbine that runs at such a high temperature and pressure that the steam pipes feeding it glow a dull red. The steam is at 1500 lb pressure and at a temperature of 1050F. This is 50° higher than any temperature previously used in turbines. To operate in the dull-red region all high-pressure parts of the turbine were made of 18-8 stainless steel. Fabrication of parts from this hard-to-work material was difficult.

Each 50-deg. increase in the steam temperature means a saving of about 1.4 per cent in fuel. Back in 1915 steam turbines averaged only 525 kw-hr per ton of coal burned. By 1945 the figure was 1550 kw-hr as an average for all plants, old and modern, then in use. This new turbine will produce about 2500 kw-hr of electrical energy from each ton of coal burned.

We All Have Them

We suppose that readers of this journal expect its articles to be couched in good English, but sometimes when we have to rewrite articles written by foreign engineers whose knowledge of English is not too good, we run into expressions that we hate to change. For instance, one writer states in his manuscript that, in a certain foreign country, shortage of labor coupled with demand for increasing production "has made painly headache to the leader of the industry." Painly headaches are not unknown to the leaders of industry in the USA either, nor to editors and acting secretaries, it might be added.

Program, Annual Meeting, AIME, San Francisco, February 13-17, 1949

MBD, Minerals Beneficiation Division; MIED, Mineral Industry Education Division; SEG, Society of Economic Geologists; IMD, Institute of Metals Division; ISD, Iron and Steel Division; EMD, Extractive Metallurgy Division.

Sunday, February 13

2 p.m.—MBD (*Business Session*).
2:30 p.m.—MIED (*Mining and Metallurgy Forum*).
7 p.m.—MIED (*Petroleum, Geology, Geophysics Forum*).

Monday, February 14

8:30 a.m.—Registration.
9 to 9:30 a.m.—Meeting of presiding officers and authors of the day.
9:30 a.m.—Section Delegates.

9:45 a.m to 12 m.

Coal Division and MBD (*Preparation*).
Health and Safety in Mines.
Industrial Minerals Division.
MIED.
Institute of Metals Division.
Iron and Steel Division.

12:15 p.m.—All-Institute Luncheon.

2:30 p.m.

Section Delegates.
Mining Methods Committee.
MBD (*Grinding*).
Industrial Minerals Division (*Economics*).
Petroleum Division (*Production Review*).
Coal Division (*Preparation*).
Extractive Metallurgy (*Lead and Zinc*).
Institute of Metals Division.
Iron and Steel Division.

4 p.m.—Research Committee (*Annual Meeting*).
5 p.m.—Executive Committee, Coal Div.

Evening—Informal Dinner Dance.

Tuesday, February 15

8:30 to 9 a.m.—Meeting of presiding officers and authors of the day.

9 a.m. to 12 m.

Petroleum Division (*Economics*).
Coal Division (*Preparation*).
Mining Methods Committee.
Industrial Minerals Division.
MBD (*Flotation Practice*).
Mining Geology Committee and SEG.
IMD (session preceded by business meeting).
Extractive Metallurgy (*Lead and Zinc*).

9:45 a.m.—Woman's Auxiliary (*Annual Meeting*).

11 a.m.—IMD Annual Lecture.

12:15 p.m.—Luncheons

MIED. MBD. Coal Division.
Mining Geology Committee.
Metals Branch Luncheon.

2 p.m.

Executive Committee, ISD.
Annual Institute Business Meeting followed by meeting of Board.
Mineral Economics Committee.
Mining Methods Committee.
Mining Geology Committee and SEG.
MBD (*Flotation Theory*).
MBD and ISD (*Pyrolysis and Agglomeration*).
Coal Division.
Industrial Minerals Division.
Institute of Metals Division.

Evening

Petroleum Branch Dinner.
SEG Dinner.
Stag Party.

Wednesday, February 16

8:30 to 9 a.m.—Meeting of presiding officers and authors of the day.

9 a.m. to 12 m.

Petroleum Division (*Technology*).
Coal Division.
Mining Methods Committee and Industrial Minerals Division (*Phosphate Symposium*).
MBD (*Hydrometallurgy*).
Mining Geology and SEG.
Extractive Metallurgy (*Blast-furnace Charge Preparation and Dross Treatment*).
9 to 11 a.m.—Iron and Steel Division.
9 to 11 a.m.—Institute of Metals Division.

9:45 a.m.—Woman's Auxiliary (*Round Table*).

11 a.m.—Howe Memorial Lecture.

12:15 p.m.—Luncheons

Industrial Minerals Division.
Mining Methods Committee.
Executive Committee, IMD.
U. S. Section, PAIMEG.

2 p.m.

Petroleum Division (*Technology*).
Coal Division.
Mining Methods Committee.
Mining Geology and SEG (*Atomic Mineral Deposits*).
MBD (*Hydrometallurgy*).
MBD and Industrial Minerals Division.
Industrial Minerals Division.
Powder Metallurgy.
Institute of Metals Division.

Wednesday, 2 p.m. (continued)

Extractive Metallurgy (*Lead and Zinc*).

5 p.m.—Executive Committee, Industrial Minerals Division.

Evening

Annual Banquet and President's Reception.

Thursday, February 17

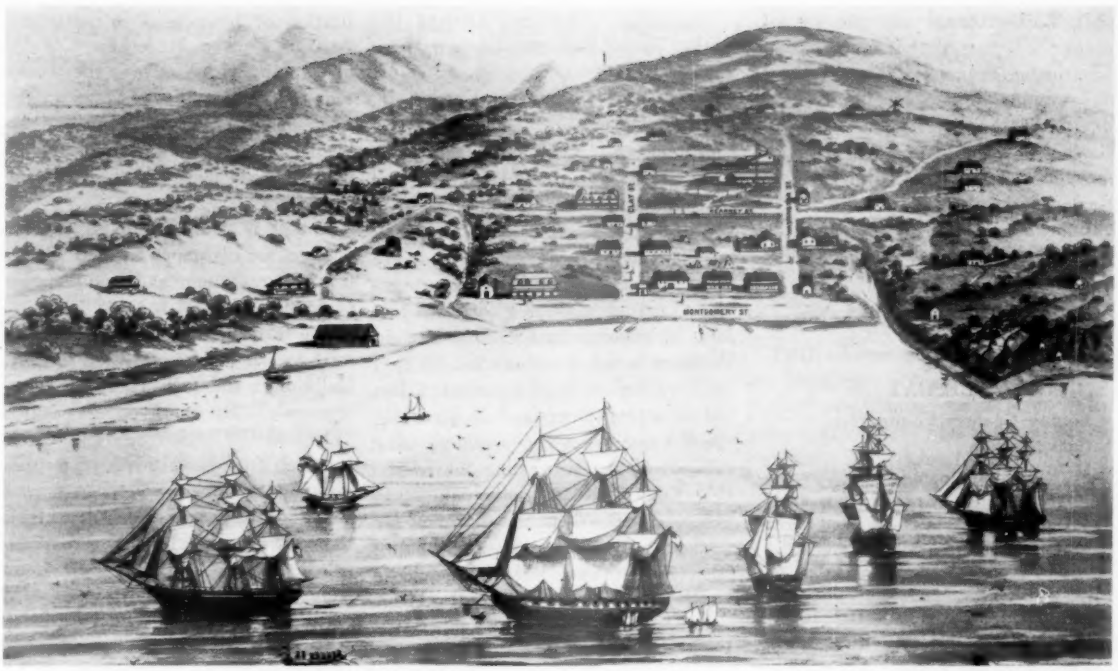
8:30 to 9 a.m.—Meeting of presiding officers and authors of the day.

9 a.m. to 12 m.

Mining Methods.
Geophysics.
MBD (*Gravity Separation*).
Extractive Metallurgy Division; Joint Session, EMB, Industrial Minerals, and Iron and Steel Divisions (*Titanium*).
Industrial Minerals Division.
Powder Metallurgy, IMD.
Executive Committee, Petroleum Division.

2 p.m.

Forum for Students.
Geophysics.
Powder Metallurgy, IMD.
MBD "Cleanup" Session.
Research Committee on Comminution.
Extractive Metallurgy (*Copper and Aluminum*).
SEG (*Geology of Ground Water*).
Executive Committee, Petroleum Division.



View of San Francisco, called Yerba Buena, before the discovery of gold in 1848.

Courtesy Wells Fargo Bank

Every Field of AIME Activity to Be Covered in Over Sixty Sessions at Annual Meeting in San Francisco Feb. 13-17

THE Institute's 1949 Annual Meeting—its 168th general meeting—will be held in San Francisco, Feb. 13-17. This is only the second annual meeting in recent years to be held outside New York City, and the first ever held on the Coast. Under the chairmanship of William Wallace Mein, Jr., plans are rapidly taking shape to make it an outstanding event. It is timed to coincide with the Centennial Celebration of the California gold rush. Entertainment will be in traditional San Francisco style, with a social program of more than usual interest. Mrs. H. Robinson Plate, Chairman, Northern California Section Woman's Auxiliary, promises the ladies a time to remember.

Technical sessions, numbering more than sixty, will be held by practically all Divisions and Technical Committees of the Institute and many group dinners and luncheons are scheduled.

Airplane flights covering points of cultural, industrial, mining, and geological interest are being scheduled for Feb. 15, 16, and 17. They will be courtesy of Pan American Airways. For details of the post-meeting tour to Hawaii see page 635, Nov. M&M. There is some talk of a winter trip to the Yosemite Valley.

Headquarters will be the Fairmont Hotel. Members who have not yet made arrangements should write for hotel reservations to AIME Housing Bureau, Room 200, 61 Grove St., San Francisco 2. Give a first and second choice of hotels, and enclose a deposit of $5 per person or $10 per room. Some informal get-togethers are scheduled for Sunday, Feb. 13, and registration starts Monday morning.

A fee of $3 will be charged members at time of registration; nonmembers, $5.

The Section Delegates meet Monday morning and afternoon. The Institute annual business meeting on Tuesday afternoon, to which all members are invited, will be followed by an executive session and a general meeting of the Board of Directors.

The welcoming luncheon for members, their ladies, and guests, will be at the Fairmont Hotel, Monday. Ticket, $3.75.

Dinner Dance, Monday evening. Ticket, $7.50.

Stag Dinner, Tuesday evening. Ticket, $10.

Institute Annual Banquet, Wednesday evening. Ticket, $10.

All reservations for functions should be made by mail to Mr. Worthen Bradley, Room 200, 61 Grove St., San Francisco, and be accompanied by check in full, payable to George H. Playter, Secretary-treasurer, San Francisco Section AIME. Tickets will be mailed for all reservations received up to Feb. 1. No advance reservations can be accepted except by mail

Dinners—The annual Branch (IMD,

ISD, EMD) dinner and the annual dinner of the Petroleum Division (Petroleum Branch) will be on Tuesday evening. Same evening, annual dinner of the Society of Economic Geologists which is meeting at joint technical sessions with the Mining Geology Committee.

Luncheons — During the Annual Meeting these special luncheons will be held:

MONDAY

All-Institute Luncheon.

TUESDAY

Mining Geology Committee.
Coal Division.
Minerals Beneficiation Division.
Mineral Industry Education Division.
Metals Branch (IMD, ISD, EMD).

WEDNESDAY

Mining Methods Committee.
Industrial Minerals Division.
Executive Committee, Institute of Metals Division.
U. S. Section, PAIMEG.

The annual meeting committees are as follows (entire personnel will be given in final program):

William Wallace Mein, J. D. Mackenzie, Donald H. McLaughlin.

General Committee: Wm. Wallace Mein, Jr., chairman; Edward Wisser, vice-chairman; George H. Playter, secretary-treasurer.

Finance Committee: Walter L. Penick, chairman; W. C. Collyer, vice-chairman; Gilfry Ward, vice-chairman.

Entertainment and Hospitality Committee: Worthen Bradley, chairman; Granville S. Borden, vice-chairman.

Advisory and Reception Committee: Robert A. Kinzie, chairman.

Banquet Committee: Walter L. Penick, chairman; Worthen Bradley, vice-chairman.

Dinner-Dance Committee: P. R. Bradley, Jr., chairman.

Stag-Smoker Committee: Herbert A. Sawin, chairman; Granville S. Borden, vice-chairman.

"All-Institute" Luncheon Committee: George H. Playter, chairman.

Hotel Committee: W. W. Bradley, chairman: E. B. DeGolia, vice-chairman.

Publicity Committee: Lewis A. Parsons, chairman.

Education Committee: Carlton D. Hulin, Lester C. Uren, Edward Wisser, Bernard York.

Field Trip Committee: Gordon I. Gould, chairman.

Authors and Presiding Officers— Get-together after-breakfast meetings of presiding officers and authors will be held at 9 to 9:30 a.m., Monday, and 8:30 to 9 a.m., Tuesday, Wednesday, and Thursday. The meetings will be casual in nature—they will afford an opportunity for authors and chairmen to ask questions and for the Institute staff to impart pertinent detail on arrangements and facilities at specific sessions. The presiding officers' envelopes, containing the available papers, written discussion, etc., will be distributed to the chairmen of sessions at these meetings, and chairmen and authors will have opportunity to become acquainted.

Robert Gordon Sproul, president, University of California, will be the principal speaker at the Annual Banquet at the Palace Hotel on Wednesday night, at which honors will be conferred as follows:

Charles F. Rand Medal to Harry Carothers Wiess (posthumously) "for energy, wisdom, and administrative ability which found expression in major contributions to the economy of the nation and the world; for high courage and vision in services to the petroleum industry; for ceaseless efforts in fostering during World War II the production of strategic supplies; for a greatness of character which showed itself in his many philanthropies and in the respect of all who knew him."

William Lawrence Saunders Medal for distinguished achievement in mining to Stanly A. Easton "for his leadership and activities over a period of fifty years in the development of the Bunker Hill and Sullivan, one of the great mining enterprises of the world."

James Douglas Medal in recognition of distinguished achievement in nonferrous metallurgy to William Wraith "for conspicuous leadership in and fundamental contribution to technologic progress in the arts of beneficiating ores of nonferrous metals, especially those of copper."

Erskine Ramsay Medal in recognition of distinguished achievement in the production, beneficiation, or utilization of bituminous or anthracite coal to Eugene McAuliffe "for his leadership and initiative in the promotion and achievement of better safety, more efficiency, and improved working conditions in coal mining, which have led to a more healthful coal industry."

Robert W. Hunt Award to M. Tenenbaum for his paper entitled "Structure, Segregration, and Solidification of Semikilled Steel Ingots."

The Institute of Metals Division Annual Award will be presented to E. A. Gulbransen and J. W. Hickman (posthumously) for their paper entitled "Electron Diffraction Study of Oxide Films on Iron, Cobalt, Nickel, Copper and Chromium."

J. E. Johnson, Jr., Award to John Daniel Saussman for his paper entitled "Sinter Practice, Kaiser Company, Inc., Fontana, California."

Rossiter W. Raymond Award for the best paper published by a member of the Institute under 33 years of age to M. Tenenbaum for his paper entitled "Structure, Segregation, and Solidification of Semikilled Steel Ingots."

Alfred Noble Prize (joint award of the Founder Engineering Societies and the Western Society of Engineers) to Robert L. Hoss for his paper entitled "Calculated Effect of Pressure Maintenance on Oil Recovery."

Also at the banquet the following, who have been members of the Institute since 1899, and several of whom will be present, will be inducted into the Legion of Honor:

Eugene Antz	Ernest A. Hersam
George H. Ashley	Henry M. Lane
H. A. Brassert	C. M. Lewis
John Cabot, Jr.	J. F. Mitchell-Roberts
Norman Carmichael	Lord Skelmersdale
Arthur Chippendale	Harold Abbot Titcomb
Carl R. Davis	J. B. Tyrrell
T. R. Drummond	Archer E. Wheeler
Robert J. Grant	Orvil R. Whitaker
Allen C. Hardison	George B. Wilson

Lewis Emanuel Young will be introduced as President of the Institute for 1949.

Technical Program

Detailed individual Branch and Division programs, ranging from practically final to somewhat tentative, may be found in the January issues of the three AIME monthly journals as follows:

Mining Engineering: Mining Methods, Health and Safety in Mines, Minerals Beneficiation Division, Coal Di-

vision, Industrial Minerals Division, Extractive Metallurgy Division, Mining Geology, Geophysics.

Journal of Metals: Institute of Metals Division, Iron and Steel Division, Extractive Metallurgy Division.

Journal of Petroleum Technology: Petroleum Division.

Programs of the Mineral Industry Education Division and the Mineral Economics Division appear in the following pages.

See chart on page 14 for schedule of all sessions.

Mineral Economics

Three papers are scheduled for the Tuesday afternoon session on mineral economics and it is hoped to have prominent national figures to present them. The first paper, "America's Stake in the Raw Materials of the World," will point out the tremendous importance of foreign sources of mineral supply to the United States and the need for a dynamic international program to assure a continuing flow of these vital raw materials to American industry. Since strategic materials and stockpiling are an important factor in this situation there should be substantial interest both on the part of Institute members and the general public in what the speaker has to say.

The second paper, entitled "The Future of Gold as a Base for the Monetary Systems of the World," will be presented by a monetary expert not identified with the gold mining industry. An analysis of past trends, the present situation, and the outlook for the future should be of value to the mining industry in general and particularly to that segment of the industry where gold production is an important source of revenue. As the third paper, "International Co-operation in Mineral Production under the Proposed Charter for the International Trade Organization of the United Nations" will deal with the future of cartel and other production-control agreements in the mineral field. The session is under the auspices of the Institute's new Mineral Economics Division.

MIED Program of Widespread Interest

All members of the Institute should look into the program of the Mineral Industry Education Division as there is something of interest to mining, metallurgy, geology, geophysics, and petroleum men. The usual Sunday afternoon and evening sessions will be held in the Hearst Mining Building on the University of California campus, Berkeley. They will be in the nature of forums: afternoon, on mining and metallurgy; evening, geology, geophysics, and petroleum. Two able moderators will lead the discussion: J. R. Van Pelt, Jr., in the afternoon, and E. DeGolyer in the evening. The speakers, men from industry, will have papers on present-day research problems in their own fields and possibly will indicate what the engineering curricula of the future should contain in order to answer better the problems of today and the future. Time will be allowed for discussion toward the end of each session.

A buffet supper at the Men's Faculty Club will follow the Sunday afternoon session.

The Division will hold a third session Monday morning and will meet at luncheon on Tuesday.

Student Forum, Tuesday afternoon.

The program follows (exact titles in final program):

Sunday Afternoon and Evening

Theme: Mineral Engineering Education of the future in the light of present-day research problems.

AFTERNOON SESSION—MINING AND METALLURGY

J. R. Van Pelt, Jr., moderator. C. E. Lawall, Coal Mining; J. H. Rahilly, Metal Mining; A. B. Cummins, Industrial Minerals; D. S. Eppelsheimer, Physical Metallurgy; also papers on Extractive Metallurgy and Mineral Preparation.

BUFFET SUPPER

EVENING SESSION—GEOLOGY, GEOPHYSICS, AND PETROLEUM

E. DeGolyer, moderator. Gustav Egloff, Petroleum Refining and Synthetic Fuels; G. C. Gester, Petroleum Geology; Morris Muskat, Production Research—Present and Future; A. C. Rubel, Production Engineering; W. H. Geis, The Professional Engineer; also paper on geophysics.

MONDAY MORNING

H. E. Nold, Registration of Engineers; J. P. Spielman, Metallurgy Courses; M. I. Signer, Mining Courses; J. D. Forrester, Graduate Study; W. B. Plank, Enrollment Statistics.

TUESDAY NOON

MIED luncheon and business meeting.

Petroleum Division

Four sessions and the annual dinner have been arranged. The production review, Monday afternoon, will consist of eight or nine regional presentations, both domestic and foreign. As at New York last February, these presentations will cover the high lights and exclude detailed statistical material. Tuesday morning will be devoted to economics and it is planned to review the California, national, Canadian, and world oil situations. Prominent and authoritative speakers will be listed in the final program. The two sessions on Wednesday will be on technology and the material in sight may make a session necessary on Thursday morning.

The principal speaker at the dinner on Tuesday evening will be Reese Taylor, president, Union Oil Co. of California. The dinner will be the occasion, too, for the presentation to F. Julius Fohs and J. B. Umpleby of the Division's Certificate of Service Award, which went last year to Earl Oliver, Fred Plummer, and Eugene Stephenson. At the dinner, I. W. Alcorn turns over the gavel to Lloyd Elkins, Chairman for 1949.

At the Sunday evening forum of the Mineral Industry Education Division, E. DeGolyer will act as moderator of the discussion on geology, geophysics, and petroleum. (See MIED program.)

The Institute Research Committee will meet at 4 p.m., Monday.

Robert Hoss will receive the Alfred Noble Prize at the banquet Wednesday evening, for his paper, "The Calculated Effect of Pressure Maintenance on Oil Recovery," published in *Petroleum Technology*, September, 1947.

Metals Branch

The Institute of Metals Division (ferrous and nonferrous physical metallurgy) will hold eight or nine

sessions running throughout the meeting; among them, sessions on properties, plastic flow, grain growth and texture, and phase diagrams, three powder metallurgy sessions, a general session, a sintering symposium, and a sintering seminar. Early in the week the Iron and Steel Division will hold four sessions, among them sessions on steelmaking and sulphur in the coke oven and blast furnace. It will also meet with the Minerals Beneficiation Division at the session on pyrolysis and agglomeration and with the Extractive Metallurgy Division on the smelting of titanium ores.

The Metals Branch luncheon (IMD, ISD, and EMD) will be held Tuesday. The Institute of Metals Division Annual Award will be announced at the banquet. The paper for which the award is made this year appears in *Metals Technology*, October, 1946, and is entitled "An Electron Diffraction Study of Oxide Films Formed on Iron, Cobalt, Nickel, Chromium, and Copper at High Temperatures"; authors, E. A. Gulbransen and J. W. Hickman (deceased).

The Annual IMD lecture will be delivered Tuesday morning (11 a.m.) by Egon Orowan, of Cambridge University.

The Howe Memorial Lecture by John Chipman, head, department of metallurgy, MIT, is scheduled for Wednesday morning at 11 o'clock.

Research

The Institute Research Committee, Elmer R. Kaiser, Chairman, will meet at 4 o'clock, Monday.

PAIMEG

The United States Section, Pan-American Institute of Mining Engineering and Geology, will meet at luncheon on Wednesday. Coking possibilities in Colombia may be a topic of discussion.

Mining Methods

Appropriately — in harmony with the Centennial celebration of the California gold rush—the initial paper (Monday afternoon) is "One Hundred Years of Placer Gold Mining in California," by Herbert A. Sawin. The papers—there are six sessions—run the gamut of mining subjects: alluvial mining, opencut mining, drills and drilling, sublevel stoping, caving operations, dump leaching, pumping, etc. A feature is the eight-paper symposium on phosphate mining on Wednesday morning. At the luncheon that day, motion pictures of the old Cornish engines in England will be shown.

Health and Safety in Mines

Monday morning session, avoiding conflict with Mining Methods, four papers, among them, "Safety in Mining at the Andes Copper Mining Company," by Charles M. Brinckerhoff.

Minerals Beneficiation Division

As an appetizer before contemplating the huge technical repast of the MBD, may we suggest the Wednesday afternoon (Noralyn) session, at which will be described the many innovations at the largest and most modern plant of its kind ever built, namely the new phosphate washery of the International Minerals and Chemical Corp., at Mulberry, Fla. Now for the entire bill, by sessions:

Monday morning, coal preparation, Coal Division supplying the program; afternoon, grinding; Tuesday morning, flotation practice; afternoon, flotation theory; afternoon with ISD, pyrolysis and agglomeration; Wednesday morning and afternoon, hydrometallurgy; Wednesday afternoon, jointly with Industrial Minerals Division, Noralyn washery; Thursday morning, gravity separation; Thursday afternoon, "cleanup" session; same afternoon, meeting of Research Committee on Comminution.

The ladies are welcome at the MBD luncheon on Tuesday.

Coal Division

A special three-session symposium on coal preparation, and three sessions on coal-mining problems. The general theme is geared to the growing industrial development of the West and the function of coal in this picture. (Annual luncheon, Tuesday.)

Space does not permit a general survey of six sessions so let's spotlight here and there. Take Monday afternoon: G. A. Vissac, prominent consulting engineer of Vancouver, B. C., will discuss the heat-drying of coal in its technical aspects. The removal of bed moisture from the fine sizes of subbituminous coals in fluidized condition at high capacities will be discussed by V. F. Parry and associates. W. M. Bertholf and J. D. Price will describe a well-tried installation of six vibrating filters for coal sludge which have operated at the Pueblo washery since 1936. So successful has the installation been that it has saved 1400 operating shifts in the washery in the past twelve years, equivalent to a gain of about 2,000,000 tons in production.

Two more quick shifts of the spotlight before the make-up man's scissors start cutting: Tuesday morning session—Another means of clarifying coal-washery water will feature the Dutch cyclone in the opening paper. So successful has been the installation of an experimental but full-size cyclone thickener at the Shamrock, W. Va., mine of the Truax-Traer Coal Co., that several other cyclones have been ordered. This paper is by Thomas Fraser, R. L. Sutherland, and F. F. Giese. Tuesday afternoon, coal mining problems; e.g., trackless mining on steeply pitching thick coal beds in Wyoming, H. C. Livingston, narrator. Wednesday morning, George Hess will show how aerial photography helps in preparing contour maps for strip mines. Coal mining in our nearest-to-Russia frontier in Alaska will be discussed Wednesday afternoon by Albert J. Toenges.

Extractive Metallurgy Division

Five sessions: See chart.

Featured Monday afternoon is a group of three papers concerned with cadmium technology. G. T. Smith and R. C. Moyer describe the fire metallurgy of cadmium; G. H. Anderson describes the electrolytic cadmium practice at Risdon; and P. C. Federsen and Harold E. Lee cover cadmium recovery practice in lead smelting.

Tuesday morning, A. A. Collins reviews the effect of high copper content on the operation of the blast furnace; R. R. McNaughton and associates give results of their experiments with oxygen-enriched air both in the lead blast furnace and in the slag fuming furnace; W. S. Reid discusses sintering practice at the Selby

Smelter; and roasting developments are described in detail by J. A. B. Forster.

Wednesday morning: A three-hour round table discussion on blast-furnace charge preparation and dross treatment, organized by R. R. McNaughton. Casper Nelson will lead off with charge preparation and A. A. Collins will keynote the discussion on dross treatment.

Wednesday afternoon: H. R. Page and A. E. Lee, Jr., trace the development of the modern silicon carbide retorts from the old clay retort; R. R. Furlong and Donald Wertz describe the development of a controlled drying process for zinc retorts at Donora Zinc Works; G. E. Johnson, the development of muffle furnaces for the production of zinc oxide and zinc at East Chicago, Ind.; and T. J. Woodside describes the El Paso slag treatment plant.

The Division meets jointly with the Industrial Minerals and Iron and Steel Divisions Thursday morning for four papers on titanium metallurgy.

Thursday afternoon: Copper; aluminum.

The EMD will join with the IMD and ISD at the annual Metals Branch luncheon on Tuesday.

Industrial Minerals Division

Program somewhat tentative as to distribution of a long partial list of papers (27 at this writing) among eight sessions clearly defined as follows: Monday, resources of the industrial minerals field; afternoon, mineral economics; Tuesday morning, structural materials; afternoon, new products, processes, and techniques; Wednesday morning, jointly with Mining Methods Committee, phosphate symposium; afternoon, jointly with Minerals Beneficiation Division, four Noralyn washery papers; Thursday morning, geology of industrial minerals; Thursday morning, jointly with EMD and ISD, titanium.

Executive Committee meeting, 5 p.m., Tuesday.

Division luncheon, Wednesday noon.

Mining Geology

The Mining Geology Committee and the Society of Economic Geologists meet together for four sessions —Tuesday and Wednesday morning and afternoon. The Committee also meets at luncheon Tuesday noon and the annual dinner of SEG is that evening.

The first two sessions follow an "ore-finding" theme. S. G. Lasky opens with an appraisal of our national mineral resources and there follow papers on the broader features of ore finding and engineering aspects of mineral exploration. H. C. Gunning and Roger H. McConnell will describe the role of certain structural controls in the formation of ore deposits in British Columbia and in the Coeur d'Alene district of Idaho, and Paul F. Kerr and Bronson Stringham will describe alteration effects associated with ore formation in the Silver Bell, Ariz., and Bingham, Utah, districts. R. F. Helmke will review some of the recent outstanding Western iron ore developments and J. J. Collins will describe the important role played by the copper industry in Japan.

To start off the Wednesday morning session, Reno Sales and Charles Meyer, whose paper on the vein alteration at Butte was outstanding at the Annual Meeting last February, are expected to repeat their fine presentation with a paper on the vein formation at Butte. Also on the agenda are descriptions of the Saddle Reef deposits of Bendigo, Australia, and descriptions of four important mining districts in the United States. The Wednesday afternoon session will feature six papers on atomic mineral deposits.

An exhibition of radioactive minerals together with various laboratory and field Geiger counters is planned.

Geophysics

Two sessions: Thursday morning and afternoon.

Atmospheric conditions above the Arctic Circle are much different from those in lower latitudes, with schedules laid down for operations at midnight in summer and hardly one hour with daylight in winter. This is apropos of the paper by Hans Lundberg on aerial magnetic surveys above the Arctic Circle. Dr. Lundberg will show some interesting pictures. Another paper, by Oscar Weiss, reports results with the aerial magnetometer in South Africa. Henry Faul's paper on radioactivity exploration with Geiger counters is in the November *Mining Technology*.

Woman's Auxiliary, AIME

FEBRUARY 13-17

Ladies' Entertainment Committee

Honorary Chairmen

Mrs. William E. Wrather
Mrs. Lewis E. Young

Mrs. H. Robinson Plate, *Chairman*
Mrs. Carlton D. Hulin, *Vice-Chairman*

Registration—Mrs. Granville Borden

Section Reports—
Mrs. Herman A. Prosser

Round Table—Mrs. Newell G. Alford

Membership—Mrs. Henry Y. Eagle

Reception Committee

Mrs. Newell G. Alford
Mrs. W. Sprott Boyd
Mrs. Clifford Bowie
Mrs. Worthen Bradley
Mrs. A. G. Cadogan
Mrs. Frank Girard
Mrs. George L. Harrington
Mrs. W. W. Henry
Mrs. James F. Kemp
Mrs. Jules Labarthe
Mrs. William Wallace Mein
Mrs. William Wallace Mein, Jr.
Mrs. James G. Parmelee
Mrs. A. B. Parsons
Mrs. Herbert A. Sawin
Mrs. J. H. Sampson
Mrs. O. Cutler Shepard
Mrs. George Sibbett
Mrs. Fred W. Varney
Mrs. D. N. Vedensky
Mrs. Livingston Wernecke

The tentative program follows:

MONDAY

Registration, Fairmont Hotel.
All-Institute Luncheon.
Evening Informal Dinner Dance.

TUESDAY

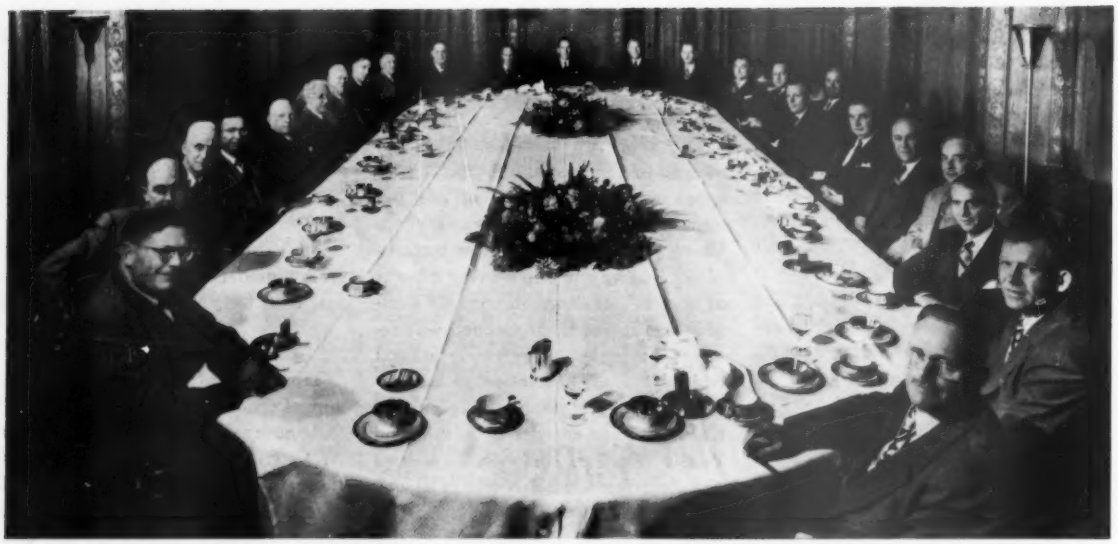
9:45 a.m. Annual Business Meeting.
12:30 p.m. Luncheon. Top of the Mark, after business meeting.
2:30 p.m. Leave by bus from Hotel for tea at Mrs. W. W. Mein's residence in Woodside.
Evening: No planned entertainment.

WEDNESDAY

9:45 a.m. Annual Round Table discussion, Fairmont Hotel; Chairman, Mrs. Newell G. Alford.
12:30 p.m. Luncheon and Fashion Show at St. Francis Yacht Club.
Evening: AIME Banquet. Palace Hotel.

Student Forum Proposed

Because of the success of a young engineers' and students' round table at the El Paso Regional Meeting, a similar session is planned for the Annual Meeting, on Thursday afternoon. Here is a chance for *would be's* to ask questions like: How much will I make on my first job as a mining engineer? Should I work for an advanced degree? What kind of training programs do the companies have? Why don't the mining companies pay as much to recent graduates as the petroleum people do?



Annual Meeting planners gathered at the Pacific Union Club, San Francisco, on Dec. 7 to forward arrangements for the February meeting. Counter clockwise, they include: E. H. Wisser, R. D. Moody, L. A. Parsons, O. P. Jenkins, L. A. Cranson, D. H. McLaughlin, E. L. Oliver, Worthen Bradley, L. C. Uren, W. L. Penick, H. N. Appleton, W. W. Mein, Jr., W. C. Collyer, G. H. Playter, Gilfry Ward, H. A. Sawin, Gordon Gould, P. R. Bradley, Jr., R. M. Searls, H. N. How, S. H. Williston, R. E. Byler, Bernard York, and L. B. Wright.

Setting Up for the Big Blast

Many San Francisco AIME members took a week off from their normal pursuits early in December to meet with Newell Appleton from AIME Headquarters to drive the final wedges in the Annual Meeting setup. It will be your fault if the machine isn't oiled by your making advance hotel reservations and purchasing tickets to social functions. You will want all the time you can get for drilling on Feb. 14 to 17, so clean your working place now so you can make her pay then. San Francisco carries the *lode;* your job is to be set up to start drilling when the air is turned on and to blast before you go off shift. Shift Boss Appleton is preparing a notice to be sent to all AIME members in the United States, Canada, and Mexico which contains full information on how to fill your oil bottle with hotel reservations, advance registration, and tickets to social affairs. You can secure your stope by making out your check to the AIME Housing Bureau, Room 200, 61 Grove St., San Francisco, $5 for one person. $10 for two.

Mrs. H. R. Plate, Mrs. C. D. Hulin, and Mrs. Worthen Bradley, of the Woman's Auxiliary, lunched at the Fairmont on Dec. 8 with H. N. Appleton and (standing) Walter Penick, G. H. Playter, Worthen Bradley, and W. W. Mein, Jr., and made plans for Annual Meeting activities.

Don't just bring your digging clothes because there is going to be an Informal Dinner Dance on Monday night in Peacock Court of the Mark Hopkins, tickets $7.50 each; a Stag Smoker at the Commercial Club on Tuesday night at $10 apiece; and on Wednesday, the Annual Banquet at the Palace Hotel, also for $10. Full lunch buckets will be provided at various Divisional and Committee luncheons. If things get too tough underground, you can take to the air for a field trip around the Bay industrial area in a Pan American airplane. The only charge for this trip will be for transportation to the airport. On Friday at 8 a.m. a field trip will leave for the San Andreas fault; tickets are $5 per person.

The ore body has been delimited, all we need now is the miners to break the rock. We'll see *you* at San Francisco.

Book Reviews

Price Control in the Metal Industries

The History of Basic Metals Price Control in World War II. By Robert F. Campbell. Columbia University Press. 1948. 263 p. $3.25.

REVIEWED BY SIMON D. STRAUSS

Robert Campbell has diligently assembled a lot of facts about the history of price control during World War II as it affected the iron, steel, and nonferrous metal producers. It does not make exciting reading, possibly because the facts themselves are not too exciting, although at the time there undoubtedly were a good many people who worked up a great deal of high blood pressure over some of these controls.

As is to be expected from an official historian of the OPA, the conclusions are generally favorable to the Office of Price Administration, and the author feels in fact that if any error was made it was on the side of liberality by OPA in allowing price increases, particularly in the steel industry. Professor Campbell apparently is not too well acquainted with the mining and metal industries themselves, for his text gives repeated evidence that he suffers under the customary layman's inability to distinguish between ore and metal. Thus he speaks for instance of several sources of imported ores as being Chile for copper, Mexico for lead, and Mexico, Peru, and Belgium for zinc. Substantially all of our imports of Mexican lead are in the form of metal and not of ore, and, of course, Belgium produces no zinc ore, being an importer of ore and an exporter of metal.

A great deal of attention is paid to the premium price plan, which was largely evolved by OPA officials. Professor Campbell makes much of the fact that this plan had to be literally forced down the unwilling throats of the WPB and the RFC. He refers to the plan as being intended to maintain and expand production of copper, lead, and zinc without greatly increasing the general level of prices, but when he discusses the results of the plan he fails to point out that actually production decreased in all three of the metals from the 1942 level, when the plan went into effect, through the end of the war. Of course, this was not necessarily the plan's fault, since primarily the drop in production reflected a shortage of labor.

On the whole, the book is of value primarily to persons contemplating the re establishment of price controls in the metal industries in the event of a future war. It is to be hoped, therefore, that it will rest long, comfortably, and undisturbed on the book shelves.

Industrial Air Sampling and Analysis

Veterans and newcomers in the field of industrial hygiene now have recourse to a reference manual, "Industrial Air Sampling and Analysis," by Leslie Silverman, that covers the latest developments on the control of contaminants in workroom air.

The Industrial Hygiene Foundation has just issued this bulletin for the benefit of its member companies, industries interested in advancing employe health and improving working conditions.

Nonmember companies and individuals may order the bulletin for $1.50 from the Foundation's headquarters, 4400 Fifth Ave., Pittsburgh 13.

What Went on at Recent Local Section Meetings

SECTION	DATE	PLACE	PRESIDING OFFICER	ATTENDANCE	SPEAKER, AFFILIATION, AND SUBJECT
Arizona, Ajo Subsection	Nov. 11	Ajo	William Keener	15	John Prendergast, power-plant superintendent, New Cornelia Branch, Phelps Dodge Corp. Discussion of Ajo Power Plant(Phelps Dodge).
Boston	Nov. 1	Smith House, Cambridge	George P. Swift	46	Roscoe J. Whitney, consulting engineer, Leominster, Mass. Hunting Pegmatites from the Air.
Carlsbad Potash	Oct. 22	Carlsbad	R. H. Allport	70	William E. Wrather, director, U. S. Geological Survey. Oil Production in the Middle East.
Carlsbad Potash	Nov. 18	Carlsbad	R. H. Allport	70	T. M. Cramer, vice-president, U. S. Potash Co. Early Developments in the Potash Basin.
Chicago	Nov. 3	Chicago Bar Assn.			Claudia Boyington, editor, industry relations section, *Ceramic Industry*. History and Production of American China.
Detroit	Nov. 22	Detroit		100	F. N. Rhines, Carnegie Institute of Technology. Sintering of Metal Powders.
Lehigh Valley	Nov. 5	Hotel Bethlehem	M. L. Fuller	60	Sherwin F. Kelly, S. F. Kelly Geophysical Services. Geophysics—Twentieth Century Treasure Hunting.
Mid-Continent	Nov. 8	Tulsa	J. Murray Walker	30	Clark Millison, consulting geologist. The Core Recorder. Henry Schaefer, Stanolind Oil and Gas Co. Limestone Pore Space Studies.
New York	Nov. 16	Mining Club			William E. Wrather, director U. S. Geological Survey. Some Aspects of Our Future Mineral Supply Problem.
Ohio Valley	Nov. 3	Engineers Club, Dayton	William A. Mueller	100	Donald B. Gillies, vice-president, Republic Steel Corp. The Future of Iron Resources.
Southwestern New Mexico	Oct. 13	Bayard Lions Club.	Ira L. Wright	45	Reports on A. M. C. Convention papers.
Southwestern New Mexico	Nov. 17	Bayard Lions Club.	Ira L. Wright	45	Staff members, U. S. Smelting Refining and Mining Co. The Pachuca and Real del Monte Districts of Mexico.
Southwest Texas	Nov. 17	Corpus Christi	Raoul J. Bethancourt	146	H. M. Cooley, Bethlehem Steel Co. Casing Design Brought Up to Date.
Tri-State	Nov. 12	Picher	O. W. Bilharz	53	J. G. Evans, Gardner-Denver Co. Travelog of Africa.
Utah	Oct. 14	Salt Lake City	W. C. Page	87	T. P. Billings, manager of mines, U. S. Smelting Refining and Mining Co. History of Metal Mining and Mine Operators in Utah.
Utah	Nov. 18	Salt Lake City	J. C. Landenberger, Jr.	51	James K. Richardson, manager Utah Mining Assn. Significant Developments in the Mining Industries' Labor Relations Field.

Among the Student Associates

Colorado School of Mines

Herman Knight was given the President's gavel, to keep for a year, at the Oct. 28 meeting of the Student Chapter at the Colorado School of Mines. Other new officers are: Bill Baker, Secretary-Treasurer; T. A. Hoy and Jack Dempsey, Directors; and George W. Heim, Faculty Sponsor. The members also appointed several committees, giving each at least one senior and one underclassman. Then, under the new leaders, the group outlined a membership drive that should make the Chapter the largest in the country.

The Nov. 18 session of the Student Chapter mixed business with social activities, thereby attracting 112 members. L. W. LeRoy, associate professor of geology at the School, spoke, with colored slides, on the general geology of the Lake Maracaibo region of Venezuela. When finished, Dr. Le Roy was asked questions on foreign employment, as he has had several years' experience working abroad. —*Harvey W. Smith, Public Relations Chairman.*

University of Nevada

Business was dispensed with at the Nov. 3 meeting of the Crucible Club, and Martin K. Hannifan took over for the evening. He is a 1938 graduate of the University's Mackay School of Mines, who recently returned to the States after working as a safety engineer for the Andes Copper Mining Co., in Chile. His talk on foreign jobs, a subject of great interest to his listeners, covered the advantages and disadvantages. An informal question and answer session followed. —*William D. Williams, Secretary.*

Calendar of Coming Meetings

JANUARY

5 **Chicago Section, AIME.**
6 **Reno Branch, Nevada Section, AIME.**
7 **Columbia Section, AIME.**
10 **Mid-Continent Section, AIME.**
10 **Boston Section, AIME. President W. E. Wrather.**
10-14 Society of Automotive Engineers, annual meeting and engineering display, Book-Cadillac Hotel, Detroit.
11 **East Texas Section, AIME.**
12 **El Paso Metals Section, AIME.**
12 **San Francisco Section, AIME. R. A. Kinzie, Jr., on the Lepol kiln.**
12 **Southwestern New Mexico Section, AIME.**
17 **Detroit Section, AIME. Thermodynamics.**
17 **Minnesota Section, annual meeting, Hotel Duluth, Duluth, Minn.**
18 **Gulf Coast Section, AIME.**
18 **Washington, D. C., Section, AIME.**
18-19 Symposium for Mining Engineers, University of Minnesota.
19 **Southwest Texas Section, AIME.**
20 **Mineral Industry Institute, 22nd annual meeting, sponsored by School of Mineral Engineering, Univ. of Washington, Seattle. Joint evening session with North Pacific Section, AIME.**
20 **Carlsbad Potash Section, AIME.**
20 **North Pacific Section, AIME.**
20 **Utah Section, AIME.**
21 **Oregon Section, AIME.**
24 **Alaska Section, AIME.**
24-28 American Society of Heating and Ventilating Engineers, annual meeting, Chicago.
25 **Montana Section, AIME.**
Jan. 31-Feb. 4 AIEE, winter general meeting, Pennsylvania Hotel, New York City.

FEBRUARY

1 **Society for Applied Spectroscopy, 63 Park Row, New York City, 8 p.m. F. Nolan, on fluorescence.**
2 **Chicago Section, AIME. S. J. Creswell, on the Bessemer process.**
3 **Reno Branch, Nevada Section, AIME.**
4 **Columbia Section, AIME.**
7 **Boston Section, AIME.**
8 **East Texas Section, AIME.**
9 **El Paso Metals Section, AIME.**
11-12 Association of American State Geologists, San Francisco.
11-12 New Mexico Miners and Prospectors Assn., Santa Fe.
14 **Mid-Continent Section, AIME.**
15 **Gulf Coast Section, AIME.**
15 **Washington, D. C., Section, AIME.**
14-17 **Annual meeting, AIME, Fairmont Hotel, San Francisco.**
Feb. 28-Mar. 4 ASTM, spring meeting and committee week, Hotel Edgewater Beach, Chicago.

MARCH

3-5 Symposium on Southeast mineral resources, University of Tennessee, Knoxville.
10-12 American Physical Society, Div. of Solid State Physics, Hollenden Hotel, Cleveland.
14-17 American Association of Petroleum Geologists, annual meeting, Hotel Jefferson, St. Louis.
Mar. 29-Apr. 1 Annual Safety Convention and Exposition, Hotel Pennsylvania, New York City.

APRIL

18-20 **Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Palmer House, Chicago.**
24-28 American Ceramic Society, national meeting, Netherland-Plaza, Cincinnati, Ohio.

SEPTEMBER

25-28 **Regional Meeting, AIME, Neil House, Columbus, Ohio.**

OCTOBER

17-19 **Institute of Metals Division, AIME, fall meeting, Cleveland.**

FEBRUARY 1950

12-16 **Annual Meeting, AIME, Pennsylvania (Statler) Hotel, New York City.**

APRIL 1950

10-12 **Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Netheriand-Plaza Hotel, Cincinnati.**

Missouri School of Mines

Almost 200 men got together for the Missouri School of Mines Student Chapter meeting on Nov. 10. The feature of the meeting was Burr Aton, of the Eagle-Picher Co., who presented his multitudinous audience with a talk and film on hygiene in mining and smelting. Mr. Aton discussed health protection for the workers, emphasizing silicosis and dust control. Refreshments followed.—*Albert Jones, Secretary.*

Ohio State University

As the 1948 part of the current school year drew to a close, students in the Mineral Industries Society of Ohio State University had already gone quite a ways in reaching their objective of an active and educational year. At the opening meeting, D. J. Demorest, retiring head of the department of metallurgy, spoke on "How Not to Be a Metallurgist." The other meetings consisted of a movie, "Wealth of the Andes," the introduction of new members, and business. In addition, a vigorous athletic program, directed by William H. Santschi, was started. All these activities were maneuvered by the new officers: Benjamin Roth, President; Thomas L. Chase, Vice-President; and John A. Schumann, Secretary-Treasurer.

At an organization meeting on Oct. 26, the students of petroleum and mining engineering at the Ohio State University formed the Prospectors' Club. Its purpose is to promote a joint understanding of the diversified interests of the petroleum and mining industries. Benson D. Blackie and Hartzel C. Slider were chosen as President and Vice-President respectively.

Yale University

The Yale Metallurgical Society Student Associates, numbering 25, elected their present officers and cast up a whole year's schedule at their Nov. 4 meeting. The returns of the election made D. A. Nankivell President, Harold Margolin Vice-President, V. T. Potter Secretary, and C. H. Stokesbury, Jr., Treasurer. In line with the plans arranged at that meeting, two weeks later members of the Society inspected the foundry of Sargent & Co., at New Haven.—*V. T. Potter, Secretary.*

Current Institute Papers

The following papers in the Institute monthly journals are available to members according to classification of the papers and the expressed desire of the members for the respective journals. Other members may obtain papers by purchasing the indicated issue of the journal at $0.75 per copy. There are no separate copies of the individual papers.

Mining Papers

The Ammonium Sulphate Process for the Extraction of Alumina from Clay and Its Application in a Plant at Salem, Oregon—By W. R. Seyfried. (*September Mining Technology* and *December Metals Technology.*)

A Process: Using Clay, Sulfuric Acid, and ammonia for the extraction of metal grade alumina. This installation was sponsored by the United States Government for the purpose of finding a substitute for bauxite as a source of alumina for aluminum production.

Radioactivity Exploration with Geiger Counters—By Henry Faul. (*November Mining Technology.*)

A Survey of the General Principles, recent practice, and new developments in geophysical exploration with radiation counters, as applied to the problems of surface and underground activity measurement, borehole logging, and sample analysis of radioactive rocks and ores.

The Occurrence and Mining of Solid Bitumens in Western Argentina—By Howard A. Meyerhoff. (*November Mining Technology.*)

Asphaltite Is Being Mined as Solid fuel in small quantity in Mendoza and Neuquén in west-central Argentina. The industry is handicapped by remote location and by costs that may make it noncompetitive with imported coal. Survival may depend upon development of a chemical industry utilizing the asphaltite as a raw material.

Determination of Room and Pillar Dimensions for the Oil Shale Mine at Rifle, Colorado — By Fred B. Wright and Philip B. Bucky. (*November Mining Technology.*)

This Paper Describes the Method used for determining the safe room and pillar dimensions for the oil shale mine. The work consisted of a study of the structure of the deposit; determination of the physical properties of the rocks; and centrifugal tests on scale models of the roof and pillars.

Some Postwar Problems of Geological Engineering Education—By W. T. Thom, Jr. (*November Mining Technology.*)

Geological Engineers Having Exceptional ability and thorough training are being called by the oil and mining companies in ever-increasing numbers.

These requirements probably cannot be met hereafter unless (a) the schools continually improve their "co-op" programs, and (b) unless the schools, the mineral industries, *and the professional societies* interested, see to it that the able high school students, who are "naturals" for geoexploratory work, get suitable orientation and advice before their senior year of high school.

A Review of Rock Pressure Problems—By Richard P. Schoemaker. (*November Mining Technology.*)

A Review Is Presented of Some Important results of recent research on the rock pressure phenomenon.

Photoelastic model experiments and mathematical analysis throw a new light on the mechanism of rock failure and doming in underground openings. Mathematical analysis also gives a new approach to the problems of subsidence and of "flow" of rocks under high stress.

Petroleum Papers

Stresses Around a Deep Well—By A. J. Miles and A. D. Topping. (*November Petroleum Technology.*)

In This Paper the Theory of Elasticity has been applied to the rock about a deep well. When the physical properties of the rock and the state of stress existing therein before drilling can be determined or assumed, it is possible to determine analytically the stress concentrations in the rock about the borehole.

Effect of Antifreeze Agents on the Formation of Hydrogen Sulphide Hydrate—By D. C. Bond and N. B. Russell. (*November Petroleum Technology.*)

The Effects of Various Antifreeze agents on the formation of hydrogen sulphide hydrate have been studied. On a molar basis, the relative lowering of T_M (maximum temperature at which solid hydrogen sulphide hydrate can exist in equilibrium with the given solution) is given for various agents.

Gravity Drainage Theory—By W. T. Cardwell, Jr., and R. L. Parsons. (*November Petroleum Technology.*)

The Paper Presents a Theory for estimating the rate of gravity drainage of a liquid out of a sand column. Account is taken of the variation in permeability to the liquid as the saturation in the upper part of the sand becomes less than 100 per cent. The theory is confirmed by previously published data.

Revaporization of Butane and Pentane from Sand — By C. F. Weinaug and J. C. Cordell. (*November Petroleum Technology.*)

Data Are Presented for the Pressure depletion of methane-n-butane and methane-n-pentane mixtures from an unpacked and a sand-packed constant-volume cell. The results indicate that the P-V-T equilibrium of these systems is not affected by the presence of sand.

The Effect of Permeability Stratification in Cycling Operations—By Morris Muskat. (*November Petroleum Technology.*)

Assuming Idealized Reservoir Stratification, cycling recoveries are calculated for exponential, probability, and linear permeability distributions. Break-through recoveries are computed for different degrees of permeability variation, and the total wet gas recoveries and associated total gas throughflows until the wet gas content of the flow stream falls to preassigned limits.

The Theory of Potentiometric Models—By Morris Muskat. (*November Petroleum Technology.*)

The Analytical Theory Underlying potentiometric models as analogues of reservoir flow systems is given. The manner of constructing models to simulate systems of variable thickness, permeability, porosity, and fluid density is outlined. It is concluded that isovol models adjusted for variable hydrocarbon porosity will not give correct analogies to actual reservoir fluid motion.

Coal Papers

Oil and Gas Wells Drilled through Workable Coal Seams—By A. J. Alexander. (*November Coal Technology.*)

The Paper Presents the Dangers that existed when mining coal in the vicinity of uncharted wells prior to the enactment of the Oil and Gas Laws of W. Virginia and the application of these laws, under the direction of the Department of Mines, which tend to safeguard lives and property of the State's two major industries.

The Use of Illinois Coal in the Production of Metallurgical Coke—By F. H. Reed, H. W. Jackman, and P. W. Henline. (*November Coal Technology.*)

An Experimental Coke Oven Has been developed by the authors in which coal blending may be studied. Coking results may be applied directly to com-

mercial oven practice. Studies have shown that prepared coals available from the Illinois field may be used to advantage in modern ovens producing metallurgical coke for blast furnace fuel.

Cleaning Anthracite Silt for Boiler Fuel with Humphreys Spiral Separator — By W. L. Dennen and V. H. Wilson. (*November Coal Technology.*)

THE PAPER DESCRIBES THE FIRST Anthracite silt cleaning plant using the Humphreys spiral separator, and the results obtained in the first year's operation.

Determination of Petrographic Components of Coal by Examination of Thin Sections—By B. C. Parks and H. J. O'Donnell, (*November Coal Technology.*)

THIS PAPER REVIEWS THE BUREAU'S terminology of describing components of coal and type classification of coals from microscopic analysis. It describes experimental tests to determine accuracy achieved in making petrographic analyses of coal by thin-section microscopy and presents data summarizing results. The practical application of analyses of coal by microscopic method is discussed.

Coal Dock Operations of the North Western-Hanna Fuel Co. at the Head of the Lakes—By J. T. Crawford. (*November Coal Technology.*)

THIS PAPER, WHICH INCLUDES A BRIEF history of coal dock operations, is largely devoted to a description of operating practices and problems of five coal docks at the ports of Duluth, Minn., and Superior, Wisc. Included are general details of moveable bridges, their associated screening plants and other equipment required for the unloading of bulk coal carriers, the storage on the docks, and the preparation and reloading of coals for distribution by rail and truck into the area serviced by the Lake docks.

Metals Papers

Temper Brittleness of Plain Carbon Steels—By L. D. Jaffe and D. C. Buffum. (*December Metals Technology.*)

IT IS SUGGESTED THAT PLAIN CARBON steels are susceptible to temper brittleness, and that temper brittleness develops so rapidly in these steels that even drastic quenching from a high tempering temperature is insufficient to suppress it. Limited experimental results support this theory.

Hydrogen in Aluminum—By Y. Dardel. (*December Metals Technology.*)

SUGGESTION OF A NEW METHOD TO Determine the amount of dissolved hydrogen in liquid as well as in solid metal has been made. The sample is first melted if solid, then held at constant temperature, and the hydrostatic pressure above is slowly lowered. When the first bubble appears, the pressure is read and a nomogram gives the corresponding hydrogen amount. The solubility of hydrogen in solid aluminum is very small. It varies from 0.058 cm^3/100 g at 659C to about 0.015 cm^3/100 g at 550C.

Lead-grid Study of Metal Powder Compaction—By Robert Kamm, M. A. Steinberg, and John Wulff. (*December Metals Technology.*)

WITH THE AID OF CIRCULAR-HOLED lead grids, it is shown in the present paper that the compaction of metal powder compacts is primarily aided by die wall lubrication. High pressing speeds and vacuum pressing do not appreciably affect green density but may influence sintered density.

Morenci Smelter of Phelps Dodge Corp., Morenci, Arizona—By L. L. McDaniel. (*January Journal of Metals.*)

OPERATING PRACTICE OF THE NEW Morenci smelter, Morenci, Ariz., has never been described, and it is the purpose of this paper to discuss metallurgical and operating practice and to describe structural features of the completed plant and to show drawings, photographs, and tabulations of the results in support of the article.

The Interaction of Liquid Steel with Ladle Refractories—By C. B. Post and G. V. Luerssen. (*January Journal of Metals.*)

THE CLEANNESS OF BASIC ARC MELTED steel is influenced by the manganese and silicon contents. The reaction of liquid steel with ladle refractories, and subsequent contamination of ingots with nonmetallics, account for this effect. Cleaner steel can be obtained if the manganese and silicon contents are made substantially equal.

The Influence of Temperature on the Affinity of Sulphur for Copper, Manganese, and Iron—By E. M. Cox, M. C. Bachelder, N. H. Nachtrieb, and A. S. Skapski. (*January Journal of Metals.*)

EQUILIBRIUM CONSTANTS OF THE REACtions *Metal Sulphide* + H_2 = H_2S + *Metal* were measured. The affinity of sulphur for copper is greater than that for iron and exceeds that for manganese above 1350C. It is concluded that increasing amounts of copper in scrap raise the sulphur content of the bath in the open-hearth process.

Plastic Deformation Waves in Aluminum—By Andrew W. McReynolds. (*January Journal of Metals.*)

PLASTIC DEFORMATION IN ALUMINUM alloys is found to occur not continuously, but by the repeated propagation of plastic waves. The resulting stress-strain curve consists of regularly spaced rectangular steps. The effect results from the presence of alloying elements, probably by precipitation, and occurs only within a range of temperatures.

On the Structure of Gold-silver-copper Alloys—By J. G. McMullin and J. T. Norton. (*January Journal of Metals.*)

THE CONSTITUTIONS OF A NUMBER OF gold-silver-copper alloys were investigated by X-ray diffraction methods. A two-phase field was found to extend from the silver-copper binary into the ternary system as far as the 75 weight per cent gold alloys. The equilibrium limits of this two-phased region are outlined at several temperatures.

Stress and Strain States in Elliptical Bulges—By C. C. Chow, A. W. Dana, and G. Sachs. (*January Journal of Metals.*)

THE STRESS AND STRAIN STATES FOUND in two elliptical bulges and one circular bulge contour of cartridge (70-30) brass were analyzed. The strains were determined experimentally while the stresses were calculated by using the equation for equilibrium of a shell and several laws of plasticity. In addition the several universal stress-strain relations were studied.

A Study of Textures and Earing Behavior of Cold-rolled (87-89 Per Cent) and Annealed Copper Strips—By Ming-Kao Yen. (*January Journal of Metals.*)

THIS PAPER DEALS WITH THE TEXTURES and deep-drawing properties of five types of commercial copper strips after 87 to 89 per cent final reduction and annealing. The influence of impurities, especially phosphorus, is given particular attention. A correlation between the formation of textures and earing behavior is reported.

Use of Electrical Resistance Measurements to Determine the Solidus of the Lead-tin System —By Ralph Hultgren and Stanley A. Lever. (*January Journal of Metals.*)

A METHOD OF DETERMINING THE solidus of an alloy by means of electrical resistance measurements taken under equilibrium conditions at successively higher temperatures is described. The method was found to be convenient, reproducible, and highly sensitive. The results agree closely with those of other observers.

Transient Plastic Deformation—By R. P. Carreker, J. G. Leschen, and J. D. Lubahn. (*September Metals Technology.*)

EXPERIMENTS PERFORMED WITH LEAD, copper, and an aluminum alloy qualitatively confirm predictions made in the preceding paper of transient effects in deformation. The effects of sudden changes in stress, temperature, and strain rate, and of cyclic loading are considered.

News of AIME Members

Don U. Deere is on leave of absence from the University of Puerto Rico and is doing graduate work in geology at the University of Colorado, Boulder.

Alfred S. Geldman, who had been resident engineer in charge, American Silver Corp., Los Angeles, is now assistant superintendent of the Monolith Portland Cement Co., Monolith, Calif.

T. S. Lovering, of the U. S. Geological Survey, delivered a lecture at the University of Kansas on Nov. 22 on "The Drive for Minerals."

W. W. Taylor has been with Stone & Webster since his return from Chile and is now in charge of their work on the construction of the Texas Gas Transmission Corporation's gas line from Carthage, Texas, to Middletown, Ohio. He may be addressed in care of that company, Steuck Bldg., Memphis, Tenn.

With the Mining Men

John R. Castano, who graduated from the College of the City of New York last June, is now a graduate assistant in geology at Northwestern University, Evanston, Ill.

John C. Chew graduated from Penn State last June with a B.S. degree in mineral economics and geology. Since then he has been working with the Phelps Dodge Copper Products Corp. as an engineer in a trainee capacity. The program is designed to acquaint the fledgling engineer with the various plants or those of most importance. He has worked at the wire and tube mill in the Bayway plant at Elizabeth, N. J., and at the Inca Mfg. division (enameling and insulation) at Fort Wayne, Ind. About the middle of January he expects to be transferred to the Habershaw division at Yonkers, N. Y., for the final phase of training.

George Bryan Coggins has been shifted to the Asheville, N. C., office of Bee Tree Vermiculite Mines, Inc. His mail goes to 201 Public Service Bldg.

In the first issues of the new magazines we are glad to tell members of the engagement of **Irene P. Klein** and **Ernest H. Sharp.** Wedding bells will ring Jan. 15. Members who visit Institute headquarters know Miss Klein as the friendly person who greets them as they step off the elevator, and who helps them with their problems, both professional and personal. Mr. Sharp, a Michigan College of Mines man, has worked in South America for the Anglo-Chilean Consolidated Nitrate Corp. and Cerro de Pasco, and in the States more recently with the Bureau of Mines, the FEA in Washington, and is now with Eagle-Picher in New York City.

Evan Bennett has moved to Chattanooga, Tenn., and resides at 4104 St. Elmo Ave.

Charles M. Brinckerhoff has been appointed general manager of the Chile Exploration Co. at Chuquicamata, Chile. **N. F. Koepel** takes over as general manager of the Andes Copper Mining Co. and the Potrerillos Railway Co. in Mr. Brinckerhoff's stead.

Edwin H. Crabtree, Jr., now of Eagle-Picher Mining and Smelting Co., First National Bank Bldg., Miami, Okla., has gone there from Tucson, Ariz.

William E. Crawford, former mill superintendent of Berens River Mines Ltd., is now addressed in care of the Quemont Mining Corp., Noranda, Que.

Forbes B. Cronk, general mining engineer for Oliver Iron Mining Co., receives his mail at 2416 East Third St., Duluth 5, Minn.

Robert J. Dalton is president and general manager of the Faire Mining Corp., 511 Baseline, San Bernardino, Calif.

James S. Dodge, Jr., wrote on Oct. 18 from his address, Natural Resources Section, GHQ, SCAP, APO 500, San Francisco, that he had made recently a field examination of the large Matsuo pyrite-sulphur mine in Iwate Prefecture. He had with him a copy of the August M&M and the article on the Greater Butte project was read avidly by the Japanese. He says that it is unfortunate that most of the Japanese mining industry is unable to obtain up-to-date American mining literature. Lack of a world monetary exchange rate prevents it.

J. Ward Downey has severed his connection with the Westvaco division of Food Machinery and Chemical Corp. For the past two years he has been mine superintendent at their property in Green River, Wyo., sinking a shaft and developing a large deposit of trona. His new address is Rm. 204, 1045 Sansome St., San Francisco, where he is engaged in consulting work, specializing in mine design and development.

Elmer R. Drevdahl, Jr., is working as a mining engineer on the engineering staff of the Inter-State Iron Co., Hibbing, Minn.

Joseph B. Elizondo has been acting as assistant geologist for the Cerro de Pasco Copper Corp., Cerro de Pasco, Peru, since his arrival in August.

R. H. S. Ewins, formerly with Lake George Mines, Captain's Flat, N.S.W., is now addressed Uruwira Minerals Ltd., Private Bag, Tabora, Tanganyika, Africa.

Norman R. Fisher, well-known mining specialist of Montreal, has been made chief consultant and mining engineer for the Greatlakes Copper Mines. He has prepared a report on drilling and the general operations at the property near Kashabowie in the Port Arthur mining division.

Victor G. Ford transferred from his job as manager of the Canutillos-Colavi section of the Bolivian Tin and Tungsten Mines Corp., to that of general manager of Cia. Minera y Agricola Oploca de Bolivia, Chocaya, on Sept. 1.

Frank W. Fruitman was honored recently by the British Government when he was named honorary officer of the military division of the Most Excellent Order of the British Empire. Colonel

Fruitman, whose address is 2919 E. 19th St., Tucson, Ariz., returned to the States last year from Germany, where he was in charge of mining and metallurgical operations in that country's western occupied zone. Before the war he was a mining and metallurgical engineer working in Arizona and California.

E. A. Gee has left College Park, Md., for Wilmington, Del., where he is a metallurgist in the pigments department of E. I. du Pont de Nemours & Co., Inc.

Paul W. Graff, president of Westmoreland Mining Co., Blairsville, Pa., will be receiving his degree in mining engineering this June from Pennsylvania State College.

Norman L. Grauerholz resides in Memphis, Nebr., where he is employed by the C. B. & Q. R. R. Co.

Stanley M. Moos

Stanley M. Moos has resigned as president and general manager of the Western Machinery Co., Mexico City, to establish a new company, Ponsford-Moos Equipment Co., 100 Texas St., El Paso, Texas. The aim of the company is to sell and service mining equipment in the southwestern United States, Mexico, and Central America.

Sydney E. Helprin is now a geologist in the Frick Laboratory, Roslyn, L. I., N. Y.

Howard R. Hendricks is doing special metallurgical research work for the Mt. Isa Mines Ltd., Mt. Isa, Queensland, Australia. He will be there for about one year as he is only on loan from the Shattuck Denn Mining Corp.

Arne Hofseth joined the staff of Aktieselskapet Sydvaranger as superintendent of their iron mines at Kirkenes, Norway, in November. He had been employed for thirteen years as a mining engineer by A. S. Sulitjelma Gruber.

A. Allan Bates

A. Allan Bates can be reached at the Portland Cement Association, 33 West Grand Ave., Chicago, Ill. He is vice-president of the Association.

Frederick C. Green has been promoted to assistant general manager of the Chino mines division of the Kennecott Copper Corp., at Hurley, N. Mex. He has been with Kennecott since 1939, serving as mill superintendent and general superintendent of Chino mines.

C. S. Gwynne, who had been teaching at Mayaguez, Puerto Rico, has returned to his home in Ames, Iowa, where he resumes his work at Iowa State College as associate professor of geology.

James Allen Haertlein, on returning from Maracaibo, Venezuela, where he was employed by the Creole Petroleum Co., has settled at 44 Marion Rd., Watertown 72, Mass.

Bernhard K. Haffner can be reached care of the American Embassy, The Hague, Netherlands. He is working with the ECA Mission to The Netherlands.

Dennis F. Haley now lives at 29 East 64th St., New York, N. Y.

W. A. Hardy returned on Oct. 28 to India to resume his duties as agent and general manager of the Central Provinces Manganese Ore Co., Nagpur, C. P., India. He had been in England.

J. S. Hazen has migrated from Holyoke, Mass., to Hamilton, Ill., P. O. Box 285.

Arthur S. Hecht, consulting mining engineer for the Department of Commerce, USAFIK, Korea, recently returned from Korea to the States. He is being retained by the Civil Affairs Division of the Army to act as consultant on technical matters concerning ore beneficiation tests now in progress in this country. At present he may be contacted at 342 27 Ave., San Francisco 21.

Warren L. Howes is with Western-Knapp Engineering Co., at 220 Power Bldg., Hibbing, Minn.

H. Herbert Hughes of the Studebaker Corp. is working for the ECA in Paris. He can best be reached now by addressing him Paris (ECA), care of Department of State Mail Rm., Washington 25, D. C.

Charles F. Joy, formerly with the International Smelting and Refining Co. as assistant geologist at the North Lily mine in Eureka, Utah, is now resident geologist at the Shoshone division of the Anaconda Copper Mining Co. in Tecopa, Calif.

M. R. Klepper, geologist for the USGS, receives his mail at 157 So. Howard St., Spokane 8, Wash.

James A. Knight, who was in Reno, Nev., is now at 231 East Sixth St., Hinsdale, Ill.

F. Clyde Lendrum is now mill superintendent for Anacon Lead Mines Ltd., Montauban Les Mines, Portneuf County, Que. He was formerly with Normetal Mines Corp.

Charles A. Lindsay is production manager for the Los Angeles division of Stauffer Chemical Co. His residence is 533 Via Media, Palos Verdes Estates, Calif.

Jimmie A. Littrell, a student at the University of Arizona, lives at 53-A Polo Village, Tucson, Ariz.

Victor M. Lopez is with the Organizacion Internacional de Investigaciones, Industriales de Venezuela, Caracas, Venezuela.

Anthony M. Mastrovich, formerly with the U. S. Vanadium Corp. at Uravan, Colo., as engineer and geologist, is exploration engineer in the western mining department of the American Smelting and Refining Co., Pacific National Life Bldg., Salt Lake City.

George E. McCormack, who has been at the Missouri School of Mines, is now working in the engineering department of the Hatfield-Campbell Creek Coal Co., Rensford, W. Va.

C. E. Miller has assumed the post of chief mining engineer with his present employers, Chrestien Mica Industries, Ltd., Domchanch P. O., Via Kodarma E. I. Rly., Behar, India.

Maurice A. Moore has moved from Kalgoorlie, W. Australia, to Ferry Rd., Southport, Queensland, Australia. He is with Associated Minerals Pty. Ltd.

Adolph E. Parr has left sunny Cali-

fornia for Nome, Alaska. His box number is 438.

Nels P. Peterson has left University Station, Tucson, Ariz., and is no longer available for consulting work. His new address is Box 1211, Globe, Ariz.

George W. Roddewig, consultant to the American Zinc, Lead and Smelting Co., may now be addressed at 108 S. Glenroy Ave., Los Angeles 24.

Adolph E. Sandberg is professor of geology at Lousiana State University, Baton Rouge, La.

J. Watts Scott is supervisor of mineral leases for the Tennessee Coal, Iron and Railroad Co. His mail will reach him at Rt. 1, Box 43, Jemison, Ala.

Joe W. Stewart, whose residence is 810 N. W. 41st Ave., Miami, Fla., is hydraulics engineer for the USGS.

Charles G. Tebelman, Jr., is employed by the Bethlehem Steel Co., 700 E. Third, Bethlehem, Pa.

Wilber D. Walker resides at 213 So. 9th Court, Bessemer, Ala., and is acting as industrial engineer for the Tennessee Coal, Iron and Railroad Co.

Louis Ware, president of the International Minerals and Chemical Corp., has been elected a director of the Illinois Central Railroad Co. Mr. Ware has worked in Arizona, Chile, New York, and Chicago with several well-known companies and has been with International Minerals since 1939.

Judson H. Whitman has moved south from Ketchikan, Alaska, to work in the engineering department of Pend Oreille Mines and Metals Co., Metaline Falls, Wash.

John Weldon Wilson is agent for Shell Oil Co., Las Vegas, Nev. His mail should go to P. O. Box 350 there.

Bernard York is now engaged as assistant professor of mining at the University of California, Berkeley 4, Calif.

• In the Metals Divisions

John S. Absalom is attending the Missouri School of Mines and makes his residence at 1804 Oak St., Rolla, Mo.

Karl Anson Allebach is employed as a supervisor for North American Aviation, Inc., and commutes to work from his residence at 306 Georgina Ave., Santa Monica, Calif.

William J. Bannister is manager for the Wire Mills Products Division of British Insulated Callender's Cables Ltd., Prescot, Lancashire, England.

William H. Bassett, Jr., Lieutenant Colonel in the United States Army, has trekked south from Scarsdale, N. Y., to Birmingham, Ala. His mail should be sent in care of Birmingham Ordnance Division, 734 Frank Nelson Bldg.

William Raymond Bay, Jr., is employed by Irvington Smelting and Refining Works at Irvington 11, N. J.

Thomas E. Miller, after completing his studies at the University of Kansas, joined the Oklahoma Steel Castings Co., in Tulsa.

J. B. Carlock is now chief consulting engineer for the Loftus Engineering Corp., 610 Smithfield St., Pittsburgh 22.

R. Allen Crosby is a metallurgist for Carnegie-Illinois Steel Corp. and lives at 2120 East 73rd St., Chicago 49, Ill.

George M. Gordon, chief chemist, U. S. Naval Dry Docks, Hunters Point, San Francisco, is in residence at 15 Stephens Way, Berkeley 5, Calif.

Harry P. Croft

Harry P. Croft, former director of technical control and research for Chase Brass and Copper Co.'s Midwestern division, has been named vice-president in charge of development of the Wheeling Bronze Casting Co., Moundsville and Wheeling, W. Va. He had been associated with Chase Brass in various capacities, including chief metallurgist, for 26 years. Dr. Croft, a graduate of Rensselaer Polytechnic Institute, received his Ph.D. degree in metallurgy from Case Institute of Technology in 1942.

Robert T. Howard has resigned from his job with the Los Alamos Scientific Laboratory and has joined Black, Sivalls & Gryson, Inc., 7500 E. 12th, Kansas City, Mo., where he will be associated with the quality control director.

Hjalmar W. Johnson

Hjalmar W. Johnson was recently named vice-president in charge of steel manufacturing for the Inland Steel Co. Mr. Johnson went to Inland in 1929 as assistant superintendent of blast furnaces. In 1930 he was promoted to superintendent of blast furnaces. He was made assistant general superintendent of the Company's Indiana harbor works in 1942 and remained there until 1946 when he was appointed staff assistant to the president.

Clarence B. Randall has been named assistant to the president of the Inland Steel Co. He had been vice-president in charge of raw materials since 1930. Well-known in the steel industry, Mr. Randall came to Inland Steel in August, 1925, as assistant vice-president. A graduate of Harvard University, he had previously practiced law in Ishpeming, Mich.

Wilfred Sykes' term of office as Inland Steel Co. president was recently extended by the board of directors beyond his normal retirement date of Dec. 31, 1948. He will continue his services thereafter in such capacity and for such period of time as the directors may subsequently determine.

Carl S. Wiedman is research metallurgist for the Carboloy Co., Detroit. His address is 5281 Beaconsfield, Detroit 24, Mich.

• In Petroleum Circles

Ray W. Amstutz is a petroleum engineer for Earlougher Engineering and can be reached at 319 E. 4th, Tulsa.

Edward I. Barton, junior geophysicist for Gulf Research and Development Co., receives his mail at Box 1096, Shawnee, Okla.

Frank W. Abrams

Frank W. Abrams, chairman of the board of the Standard Oil Co. of N. J., has been made national chairman of the forthcoming $15,000,000 Syracuse University building and development fund. Mr. Abrams received his civil engineering degree from the College of Applied Science at Syracuse in 1912 and an honorary LL.D. degree from the University in 1946.

E. M. Benson, Jr., petroleum engineer for the Richfield Oil Corp., may now be addressed at Box 147, Bakersfield, Calif.

Byron B. Boatright is now vice-president of the Conroe Drilling Co. with an office in the Brown Bldg., Austin, Texas.

Don R. Bowcutt, formerly of Butte, is an engineering clerk for Phillips Petroleum Co., Cut Bank, Mont.

Stuart G. Branyan, district engineer for the Carter Oil Co., receives his mail at Magnolia, Ark.

Chester U. Burk has left Texas for Oklahoma City. His mail goes care of Kobe Inc., Box 4515, S. E. 29th St., Oklahoma City.

Robert A. Cadigan is working for the USGS on the Colorado plateau project at Grand Junction, Colo.

George R. Chenot is now geologist for the Standard Oil Co. of Texas, at Dallas.

Wallace H. Collins is now with Shell Oil Co., Inc., Box 1191, Tulsa.

Maurice Deul has a job in the section of geochemistry and petrology of the U. S. Geological Survey, Washington 25, D. C.

Norman S. Domenico, after graduation from the Colorado School of Mines last spring, worked as a computer on a seismograph crew of the Atlantic Refining Co. in Wyoming. This fall he enrolled as a graduate assistant in the geological sciences division of the California Institute of Technology and is now studying toward an advanced degree. His address is 1126 Cordova, Pasadena 5, Calif.

Jules A. Durand is inspector of mines in Seine et Oise Province, France.

Wesley G. Gatlin is training as a petroleum engineer for The Texas Co. at Houma, La.

Jerry V. George is temporarily at A & M College of Texas but receives his mail at Rt. 1, Milford, Texas.

Walter F. Gerhard, with Amerada, may now be addressed at P.O. Box 103, Los Alamos, Calif.

Lee W. Gibson, consulting geological engineer, makes his office at 616 Indianapolis, Huntington Beach, Calif.

James L. Minahan

James L. Minahan, geologist for the USGS, receives his mail at Box 590, Thermopolis, Wyo.

Edward H. Griswold, petroleum engineer, has moved from Midland, Texas, to Pebble Beach, Calif.

Ellis W. Hamilton is doing production and drilling work for Kern Oil Co., Ltd., at Bakersfield, Calif.

John L. Hoyt, Jr., is assistant general superintendent for Pan American Production Co., Mellie Esperson Bldg., Houston, Texas.

Clarence B. Hussey, formerly with Gulf at Kermit, Texas, has been transferred to Odessa, Texas, where he is zone petroleum engineer for the Gulf Oil Corp.

Julian E. Huzarevich, recently of Fort Worth, is now a junior petroleum engineer for Stanolind Oil and Gas Co., Tulsa.

David J. Kull is an exploration trainee with Shell Oil Co. at Houston.

Robert M. Leibrock has moved from Arkansas to 619 N. Osage Dr., Tulsa.

W. T. Mendell is now working for himself. He will be doing consulting petroleum geology and engineering; his office is 1902 Second National Bank Bldg., Houston, Texas.

Gregor C. Merrill is Paris representative for United Overseas Petroleum Co., Ltd. His mail should be sent to 7 Place Vendome, Paris 1.

Harold L. Moseley is a petroleum engineer for D & W Oil Tool Co., Inc. He should be addressed Box 1215, Corpus Christi, Texas.

L. Murray Neumann, formerly consulting geologist with the Carter Oil Co. of Tulsa, has opened an office at 412 Palace Bldg., Tulsa.

Basil V. Savoy, who was with Central Pipe Line Co., is now a petroleum engineer for Continental Oil Co., Houston, Texas.

Ralph J. Schilthuis, assistant superintendent of the gas division for Humble Oil and 1939 Alfred Noble Prize winner, resides at 3747 Purdue, Houston.

Raymond D. Sloan has been shifted by the Carter Oil Co. from Billings, Mont., to Denver.

Dallas R. Staples, field engineer with The Texas Co., gets mail at Box 1, Premont, Texas.

Karl R. Tripp, a trainee of The Texas Co., has been moved to Pampa, Texas.

Owen M. Watkins, Jr., is now junior production engineer for the Pan American Production Co., 108½ Chaparrel, Corpus Christi, Texas.

F. Raymond Wheeler, of Chemical and Geological Laboratories Inc., has migrated from Tulsa to the Casper, Wyo., office.

Obituaries

Harold S. Munroe

A Tribute by Wilber Judson

THE many friends of Harold S. Munroe ("Jack") were deeply grieved to hear of his passing away in Miami, Fla., on Oct. 15. He had had several heart attacks during the past few years but had recovered from all of them, so he was fairly active and, while not being able to take too much responsibility, was enjoying good health and comfort. His sudden death is therefore a special shock.

Munroe had a wonderful personality, making friends easily and keeping them.

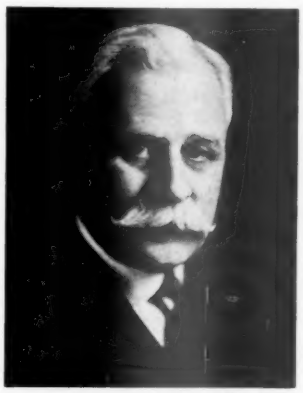
His sense of humor was delightful and it was a pleasure to be in his company. Few mining engineers have had the wide friendships he enjoyed, both in the United States and abroad, especially in England. He also had many close friends among the hard-rock miners in different parts of the world. Everyone liked him—a great tribute to any man.

I first met Munroe in Panama in 1906. Both of us were on our way to take jobs in a copper mine, in the Argentine, which closed down the following year in the depression of 1907. After that we were together in Mexico most of the time—in fact, until Munroe left there around 1913. Since that time it was my pleasure to see him fairly often, so we renewed our old friendship as often as possible.

After leaving Mexico he, in turn, was general manager of the Consolidated Coppermines in Nevada; vice-president and general manager of the Granby Consolidated Mining, Smelting and Power Co., with headquarters at Anyox, B. C.; mining engineer for The American Metal Co.; and mining engineer with the Newmont Mining Corp. Through Newmont he was employed as consulting engineer for the Rhokana Corp., owning and operating copper mines in Rhodesia. In his capacity as general manager of the Rhokana operations, he had the responsibility for equipping and operating the mine, mill, and smelter at the N'Kana mine in Northern Rhodesia—one of the largest copper mines of the world. In 1935 he returned to North America and became director and consulting engineer for Ventures, Ltd., living in Toronto. I believe it is correct to say that he was one of the great mine operators of his generation, having a flair for building and handling an organization such as few men possess.

While in Toronto he had his first heart attack, incapacitating him for continuous strenuous effort. After leaving Toronto he moved to Fort Lauderdale, Fla., and a little over a year ago he moved to Tryon, N. C. Munroe's scholastic training was at Cornell and the Colorado School of Mines. He will be missed by his many friends for whom a visit with him was a most pleasant event and happy memory.

RANDOLPH SIMPSON (Member 1940), chief metallurgist for the Electric Steel Foundry Co., died recently at his home in Portland, Oreg. A native of Massachusetts—born there 62 years ago—he migrated to Portland in 1912, soon after receiving a B.S. from Dartmouth College. In that city he did chemical work for the Santa Cruz Portland Cement Co. and the Portland Gas and Coke Co., before he went to Electric Steel. This last professional association was made in 1920.



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John Allen Coe

JOHN ALLEN COE (Member 1923), who retired recently after spending sixty years in the brass business, passed away Aug. 4, shortly before his eightieth birthday. Mr. Coe was introduced to that business through the Birmingham Brass Co., with whom he spent the first nine years of his career. When he left it, he joined the American Brass Co., in Waterbury, Conn., as a sales manager. But soon he was advanced, successively, to the positions of assistant to the president, vice-president, and president. Although he "retired" in 1945, he retained a connection with the Company, as a director.

FREDERICK GARDNER COTTRELL (Member 1912), a humanitarian who expressed his benevolence for society as a chemist, metallurgist, and inventor, died Nov. 16, while attending a business meeting of the National Academy of Sciences, at the University of California, in Berkeley. His death concluded 71 years of trying to further the comfort and well-being of humanity. And he was successful in his efforts, mainly through the Research Corp.

Dr. Cottrell established this nonprofit organization in 1912, in order to make his electrical precipitator available to everybody; he rejected the opportunity to take for himself the profits from his invention. In the years that followed, Dr. Cottrell saw that the Research Corp.'s profits went back into more research, in colleges and scientific institutions. To date, the organization has provided approximately $3,500,000 for scientific research, and the bulk of that sum has come from Dr. Cottrell's invention.

He perfected the electrical precipitator that bears his name between 1906 and 1909, while an assistant professor of chemistry at the University of California, his first *alma mater*. The other two schools he attended are the University of Berlin, where he earned an M.A. degree, and the University of Leipzig, where he earned a Ph.D.

When he left his teaching work, Dr. Cottrell joined the Bureau of Mines as a consulting chemist. From this position he was appointed, consecutively, chief physical chemist, chief chemist, chief metallurgist, assistant director, and director. During the time he was with the Bureau he developed a process for manufacturing helium gas at a cost that made it practical for popular use. He also did considerable work in the metallurgical field toward developing equipment for preheating air used in metallurgical operations.

Among his many other accomplishments was the formation of Research Associates, also a nonprofit organization. Through it, Dr. Cottrell conducted scientific and social research, attempting to eliminate, as far as possible, the time lag between the perfection of scientific ideas and their introduction into national life.

MYRIL L. JACOBS, vice-president of Bethlehem Steel Co.'s raw material properties, died Nov. 13 at the Pan American guest house, Trinidad, B. W. I., of a circulatory failure. He had been taken ill the previous evening at Bethlehem's Palua mine and flown to the Piarco airport.

Mr. Jacobs was born May 16, 1885, at Weldbank, Pa. He received his early education in the schools of the community and at Marietta College and Mercersburg Academy. In 1910 he was graduated from Lehigh with a degree in mining engineering.

He began his business career as assistant engineer for Astoria Light, Heat and Power Co. that same year. In 1912 he was employed by the Mexican Light and Power Co. as assistant engineer in charge of hydroelectric tunnels and dams. The following year he accepted a position as assistant engineer with the New York Municipal Railways in Brooklyn. In 1916 he became engineer for F. H. Clement & Co. at Bethlehem, Pa., and continued in this position until 1920.

At that time he was made general manager of quarries, for Bethlehem Steel Co., in 1934 general manager of the stone and slag division, and in 1939 assistant to the vice-president. The next year Mr. Jacobs was appointed vice-president of Bethlehem Steel Co. and president of various Bethlehem subsidiary companies engaged in mining. He was elected a director of Bethlehem Steel Corp. on Jan. 25, 1940.

EDWARD BEISEL SNYDER (Member 1926), a mining engineer who devoted his entire professional career to service with the Hazle Brook Coal Co., died on April 25, at the age of 57. Mr. Snyder first worked about the Hazle

Necrology

Date Elected	*Name*	*Date of Death*
1923	John Allen Coe	Aug. 4, 1948
1912	Frederick G. Cottrell	Nov. 16, 1948
1907	William H. Emmons	Nov. 5, 1948
1934	H. Clarence Horwood	Oct. 30, 1948
1917	Myril L. Jacobs	Nov. 13, 1948
1912	Harold S. Munroe	Oct. 15, 1948
1940	Randolph Simpson	Unknown
1926	Edward B. Snyder	April 25, 1948

Brook anthracite mines, in Pennsylvania, during his summer vacations, while a student at Lehigh. After graduation in 1914, with the degree of E.M., he started his career with the Company on a full-time basis. However, three years later, World War I intervened, and he joined the U. S. Army Artillery as a Private. When he was discharged from service in 1919, as a Second Lieutenant, he returned to Hazle Brook, and there remained until his recent death.

Proposed for Membership

Total AIME membership on November 30, 1948, was 15,433; in addition 3687 Student Associates were enrolled.

ADMISSIONS COMMITTEE

Albert J. Phillips, Chairman; James L. Head, Vice-Chairman; George B. Corless, T. B. Counselman, George C. Heikes, W. B. Plank, P. D. Wilson, E. M. Wise.

Institute members are urged to review this list as soon as the issue is received and immediately to wire the Secretary's office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified.

In the following list C/S means change of status: R, reinstatement; M, member; J, Junior Member; A, Associate; S, Student Associate; F, Junior Foreign Affiliate.

ALABAMA

Adamsville — MARSHALL, CLARENCE GANES. (M). Electrical engineer, coal mines, Tennessee Coal, Iron and Railroad Co.

ARIZONA

Humboldt — ZINKL, ANDREW JOSEPH. (R,C/S—S-M). Assistant superintendent, Iron King branch, Shattuck Denn Mining Corp.

CALIFORNIA

Alhambra—ELSON, WILLIAM HAROLD, JR. (R,C/S—S-J). Petroleum engineer, Shell Oil Co. GARDNER, JOHN WILLIS. (R,C/S—S-M). Field engineer, Gardner-Denver Co.

Bakersfield — CHARLES, WILLIAM WATHEN, JR. (C/S—J-M). Geologist, Pacific Western Oil Corp. WELLER, ARTHUR REILLY. (J). Junior exploitation engineer, Shell Oil Co.

Berkeley—PASK, JOSEPH A. (M). Associate professor of ceramic engineering, division of mineral technology, University of California (Berkeley).

Grass Valley—KREBS, RICHARD WILLIAM. (M). Mill superintendent, Idaho Maryland Mines Corp.

Hammonton—PRATT, MORTON EDISON, JR. (C/S—S-J). Research engineer, Yuba Cons. Gold Fields.

Hollywood — PENN, CHARLES JAMES. (M). Editor, *Petroleum Register*.

Keeler — MACKEVETT, EDWARD MALCOLM, JR. (C/S—S-J). Junior geologist, minerals section, U. S. Geological Survey.

Los Angeles—MACLEAN, NORMAN EWEN. (M). Southwestern sales manager, American manganese steel division, American Brake Shoe Co. NATCHER, STANLUS Z. (M). Assistant to the vice-president of conservation, Standard Oil Co. of California. PEARSON, GERALD THOMAS. (C/S—J-M). General production superintendent, Continental Oil Co. WERNER, SCOTT JOHN. (J). Petroleum engineer, Socony Vacuum Oil Co.

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Lehighton—HANDWERK, GLENN ERWIN. (J). Student engineer, Gulf Refining Co.

Pittsburgh—FLOYD, WALTER INGRAM. (A). President, Duff-Norton Co. GOLDMAN, KENNETH MARVIN. (J). Research assistant, Carnegie Institute of Technology. GULBRANSEN, EARL ALFRED. (M). Advisory engineer, Westinghouse Research Laboratories. ROWLAND, DUDLEY HAMILTON. (M). Research associate, Carnegie-Illinois Steel Corp.

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Midland — FARIS, CHARLES WILLIAM. (M). Partner, Faris & Warren.

Odessa—HARDEE, PECK, JR. (R,C/S—S-J). District engineer, Texas Pacific Coal and Oil Co. HENLEY, JACK. (J). District geologist, Lane-Wells Co.

Overton—THOMPSON, FREDERICK LUTHER, JR. (C/S—J-M). Petroleum engineer, Humble Oil and Refining Co.

Pittsburg—KENT, LEON ALFRED. (J). Engineer-draftsman, Lone Star Steel Co.

Victoria—BINKLEY, JOHN FREDERICK. (R,C/S — S-M). Petroleum engineer, Barnsdall Oil Co.

UTAH

Salt Lake City—WHITE, JOHN BLACKWOOD, JR. (C/S—J-M). Field engineer, Galigher Co.

WASHINGTON

Bellingham — PASCOE, JAMES HENRY. (M). Vice-president and general superintendent, Bellingham Coal Mines, Inc.

Metaline — SEERLEY, JOHN JOSEPH. (C/S—S-J). Mine shift boss, Pend Orielle Mines and Metals Co.

Olympia—STANTON, WILLIAM LAYTON. (M). Division geologist, Union Oil Co. of California.

SEATTLE—DONG, JAMES Y. (C/S—S-J). Chemist, Bethlehem Pacific Coast Steel Co.

WEST VIRGINIA

Fairmont—KINGERY, DONALD SAMUEL. (R,C/S—J-M). Senior mining engineer, Bureau of Mines.

Fayetteville — LONG, JOHN BROADUS. (M). President, Long Super Mine Car Co.

WYOMING

Laramie — PAINE, WILLIAM RHODES. (C/S—S-J). Graduate school student, University of Wyoming.

ALASKA

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ONTARIO

West Lorne—EVANS, JOHN ROY. (C/S—S-J). Trainee, Creole Petroleum Corp.

QUEBEC

Montreal — ROBERTSON, ALEXANDER HUGH. (M). Vice-president, Quebec Iron and Titanium Corp.

CHILE

Chuquicamata—THURSTON, FRANK EDWARD. (M). Junior engineer, Chile Exploration Co.

PERU

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Warwickshire — CROWTHER, JAMES. (M). Research metallurgist, James Booth & Co.

FRANCE

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GREECE

Laurium — CONOFAGOS, CONSTANTIN. (M). Chief metallurgist, Cie. Française des Mines de Laurium.

TANGANYIKA

Tabora — LANDCASTLE, RALPH. (M). Inspector of mines, Government of Tanganyika.

CHINA

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VICTORIA

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Robert K. Aaker ..... Univ. N. Dak.
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Howard A. Anderson, Jr. Colo. Sch. Mines
Donald I. Andrews .... Colo. Sch. Mines
Charles H. Armitage ..... Univ. Wis.
Donald G. Ashe ..... Colo. Sch. Mines
Herbert J. Ashe (Rein.) Colo. Sch. Mines
Henry E. Aviles ..... Univ. Ariz.
Robert L. Ballard ..... Ohio State
John G. Barnes ..... Univ. N. Dak.
Virgil D. Basinger ..... Ohio State
John H. Bassarear ..... Colo. Sch. Mines
James R. Bassett ..... Yale Univ.
Kenneth M. Bearden . Texas Mines & Met.
William L. Beaton, Jr. Texas Mines & Met.
Thomas E. Benedict ..... Okla. A&M
Jack B. Bennett ..... Colo. Sch. Mines
Roshan B. Bhappu ..... Colo. Sch. Mines
Irfan N. Bilen ..... Ohio State
James C. Birtell ..... Okla. A&M
Benson D. Blackie ..... Ohio State
Wayne F. Bohanan ..... Colo. Sch. Mines
Leo Borasio ..... Colo. Sch. Mines
Robert E. Bosco ..... Colo. Sch. Mines
Charles D. Bowling ..... W. Va. Univ.
Quinn G. Boyd ..... Texas Mines & Met.
Leo N. Bradley ..... Colo. Sch. Mines
Robert J. Brakey, Jr. ..... Okla. A&M
John A. Brandon ..... Colo. Sch. Mines
James E. Brazell ..... Okla. A&M
Robert E. Brooks ..... Univ. Okla.
Robert L. Brown ..... Univ. Ill.
Robert A. Burney ..... Ohio State
Robert L. Burns ..... S. Dak. Sch. Mines
Dewey J. Bushaw ..... Univ. N. Dak.
Daniel W. Butner, Jr. .. Colo. Sch. Mines
Franklin W. Butterfield ..... Univ. Nev.
Tom G. Calhoun ..... Texas A&M
Samuel H. Caran ..... Ohio State
Melvin Carlson ..... Colo. Sch. Mines
Arduino Castrale .. Mo. Mines & Met.
Clifford H. Chandler ..... Ohio State
Wei K. Chang ..... Mo. Mines & Met.
Donald D. Christofferson . Univ. N. Dak.
Robert K. Christofferson .... Okla. A&M
Donald G. Christy ..... Univ. N. Dak.
Richard J. Clifford ..... Ohio State
Robert K. Collins ..... S. Dak. Sch. Mines
Dowd L. Cooper ..... Oreg. State Coll.
Earl J. Cox ..... S. Dak. Sch. Mines
Bob C. Crittendon ..... Okla. A&M
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Karl H. DelPorte ..... Mo. Mines & Met.
Charles F. Deuel ..... Colo. Sch. Mines
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Russell P. DiSano ..... Queens Univ.
Billy F. Dittman ..... Colo. Sch. Mines
Danford J. Dodds ..... Colo. Sch. Mines
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Frank A. Foley ..... Colo. Sch. Mines
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Stuart A. Smith ..... Yale Univ.
Verne L. Snow ..... Okla. A&M
Gerald W. Spotts ..... Okla. A&M
James T. Stanley ..... Univ. Ill.
Walter L. Steinhilber ..... CCNY
Norman C. Stevenson .. Okla. Inst. Tech.
Raymond M. Stewart .. Colo. Sch. Mines
Bobby G. Stoops ..... Okla. A&M
Robert R. Strange ..... Ohio State
Erwin J. Strecker ..... Univ. N. Dak.
James R. Stringham ... Colo. Sch. Mines
Hung-Shung Sung ..... Ohio State
Horace Sutcliffe, Jr. ..... Univ. Ala.
Theodore M. Swanson ..... Univ. Minn.
Charles A. Tallard ..... Univ. Minn.
Yeshwant P. Telang ..... Univ. Mich.
Paul J. Theusen ..... Mo. Mines & Met.
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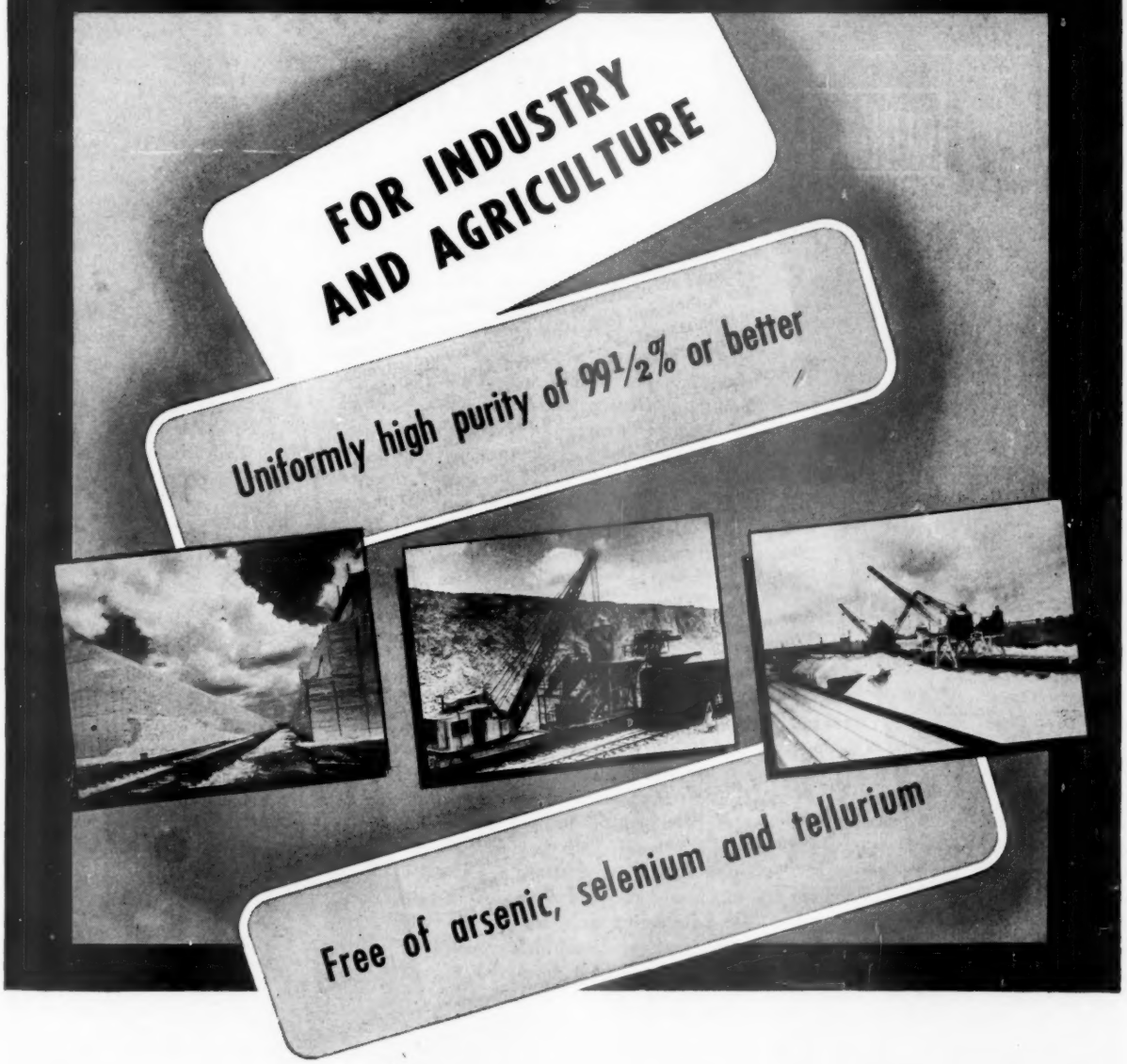

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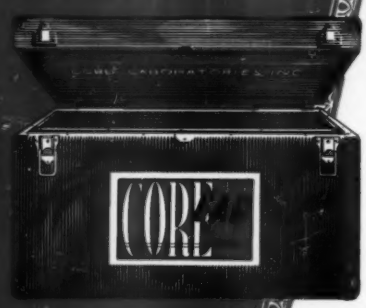

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T. P. 2510

A HYDRAULIC PROCESS FOR INCREASING THE PRODUCTIVITY OF WELLS

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ABSTRACT

The oil industry has long recognized the need for increasing well productivity. To meet this need, a process is being developed whereby the producing formation permeability is increased by hydraulically fracturing the formation.

The "Hydrafrac" process, as it is now being used, consists of two steps: (1) injecting a viscous liquid containing a granular material, such as sand for a propping agent, under high hydraulic pressure to fracture the formation; (2) causing the viscous liquid to change from a high to a low viscosity so that it may be readily displaced from the formation.

To date the process has been used in 32 jobs on 23 wells in 7 fields, resulting in a sustained increase in production in 11 wells.

INTRODUCTION

Need For Process

Although explosives, acidizing, and other methods have long been used, there still exists a need for artificial means of improving the productive ability of oil and gas wells, particularly for wells which produce from formations which do not react readily with acids. This paper discusses the development of a hydraulic fracturing process, "Hydrafrac", which shows distinct promise of increasing production rates from wells producing from any type of formation. The method is also considered applicable to gas and water injection wells, wells used for solution mining of salts and, with some modification, to water wells and sulphur wells.

Requirements of Process

In considering such a possible process, it appeared that certain requirements must be met. Some of these are as follows:

A. The hydraulic fluid selected must be sufficiently viscous that it can be injected into the well at pressure high enough to cause fracturing.
B. The hydraulic fluid should carry in suspension a propping agent, such as sand, so that once a fracture is formed, it will be prevented from closing off and the fracture created will remain to serve as a flow channel for oil and gas.
C. The fluid should be an oily one rather than a water-base fluid, because the latter would be harmful to many formations.
D. After the fracture is made, it is essential that the fracturing fluid be thin enough to flow back out of the well and not stay in place and plug the crack which it has formed.
E. Sufficient pump capacity must be available to inject the fluid faster than it will leak away into the porous rock formation.
F. In many instances, formation packers must be used to confine the fracture to the desired level, and to obtain the advantages of multiple fracturing.

Development of Process

As a necessary step in the development of this process, it was deemed advisable to determine if the Hydrafrac fluids were actually fracturing the formation or whether these special fluids were merely leaking away into the surrounding formation. To determine this, a shallow well, 15 feet deep, was drilled into a hard sandstone. Casing was set, the plug drilled, and the well deepened in the conventional manner. A fracturing fluid dyed a bright red was used to break down the formation. Sand mixed with distinctively colored solids was injected into the well with the fracturing fluid to prop open any fracture made in the formation. A simulated gel breaker solution dyed a bright blue was then pumped into the well to determine if the gel breaker would follow the first solution.

The results are shown in Figure 1. It was noted that a fracture was formed about the well bore, that the propping agent was transported back into the break, and that the breaker solution did actually follow the fracturing gel out into the fracture.

While it is realized that this shallow well test is probably not exactly equivalent to a deep test, the results were interpreted as being a definite indication of what happens down the hole during a Hydrafrac job.

Of interest in this connection is an investigation reported by S. T. Yuster and J. C. Calhoun, Jr.[1] This study, reported after the Hydrafrac work was under way, presents some excellent field data supporting the theory of fracturing a formation with hydraulic pressure.

METHOD

Steps of Hydrafrac Process

Figure 2 shows a simplified cross-sectional view of a well treated by one version of the process. The first step, formation breakdown, is done with a viscous fluid, usually consisting of an oil such as crude oil or gasoline, to which has been added a bodying agent. Due to availability and price, war-surplus Napalm has been used in the majority of experiments to date. Napalm is the soap which was used in the war to make "jellied gasoline". The next step consists of breaking down the viscosity of the gel by injecting a gel-breaker solution and then after several hours, putting the well back on production. Figure 3 shows diagrammatically, a typical field hookup. The oil or gasoline is unloaded into the 10 bbl. tank shown on the left rear of the truck. This base fluid is picked up by the mixing pump and pumped through the jet mixer, where the granular soap is added. Next it goes into a small mixing tub, from which the high-pressure pump takes suction. The solution is then pumped into the well. The breaker solution is then taken from an extra tank and is displaced into the well immediately following the gel. When required, additional trucks may

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[1]References are at the end of the paper.

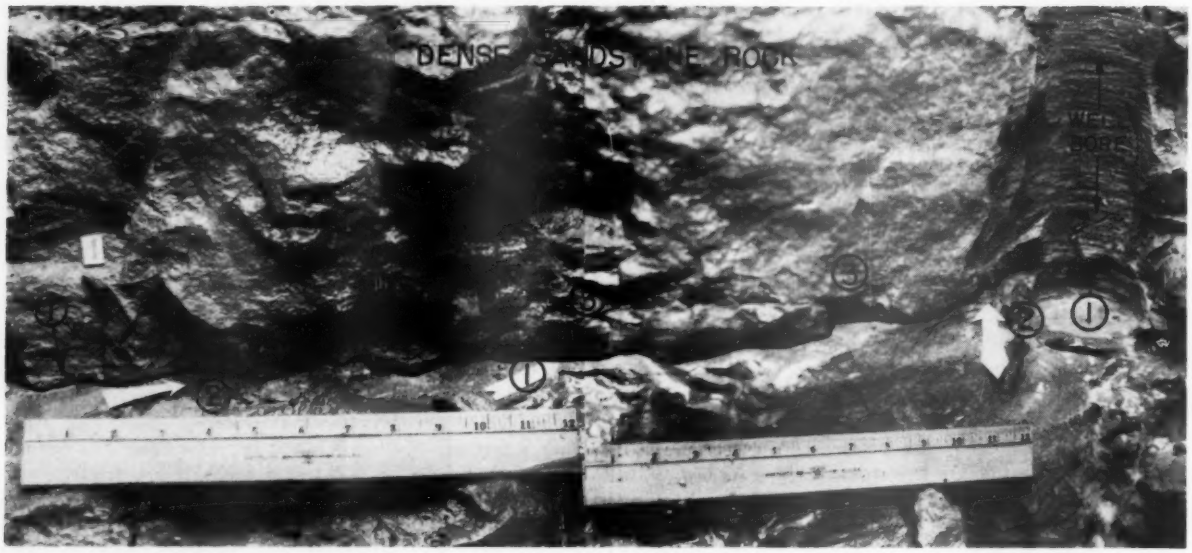

FIG. 1 — SHALLOW WELL HYDRAFRAC JOB, SHOWING (1) FORMATION FRACTURE CONTAINING FRACTURING LIQUID (2) EXPOSED FORMATION PROPPING AGENT AND (3) ROCK ADJACENT TO THE FRACTURE PARTIALLY SATURATED WITH SIMULATED GEL BREAKER SOLUTION.

be connected to the well so as to pump the fluids at a faster rate.

Planning the Field Job

The planning of a Hydrafrac job requires detailed consideration of the individual well conditions. Selection of the pumps and of the kind and amount of hydraulic fluid, for example, depends upon the thickness and permeability of exposed producing formation; the bottom hole formation pressure; the well depth; the pipe size and condition; and upon the weight, strength, and compressibility of the overburden.

Individual items that must be considered in the planning, and the method of meeting the detailed requirements for the fracturing fluid and equipment are discussed in detail below, under the corresponding headings of hydraulic fluid requirements, pump requirements, and packer requirements.

Hydraulic Fluid Requirements

The usual hydraulic fluid requirement is for an oil phase material with viscosity between 50 and 150 centipoises or higher, depending on the individual job. It has been found that Napalm soap and similar soaps provide the desired characteristics. Napalm can be added to gasoline, kerosene or other refined petroleum cuts to produce gels having any desired viscosity up to considerably over 300 centipoises.

Hydraulic Base Fluids: The ideal fluid should be an oily one rather than a water base fluid, to avoid decreasing the permeability of the formation to oil or gas. This requirement is met by the Napalm gel being used. Water base fluids, however, would be advantageous in treating water wells, or water injection wells used in either the oil industry or industries where water is used in solution mining of salts, and in the Frasch process of mining sulphur. There is also some reason to believe that a water base fluid could be used successfully in oil or gas wells. In other words, it is entirely possible that the benefits derived from hydraulically fracturing the formation may be great enough to overcome the decrease in permeability caused by water wetting of the oil or gas sand. It is known, for example, that limestone reservoirs can be acidized with an acid solution that is as high as 80 or 90 per cent water, with a resulting increase in well productivity. Future work with this process may indicate that it is more economical to use a water base for the hydraulic fracturing fluids than the more expensive gasoline and crude oil base fluids, particularly in formations not appreciably contaminated with argillaceous materials.

Sand Carrying Capacity of the Fluid: It is often desirable that the hydraulic fluid should carry in suspension a sufficient amount of strong granular material such as sand to be used as a propping agent to keep the fracture from closing off after release of pressure. The high viscosity of the Napalm gels makes them well suited to transport such material.

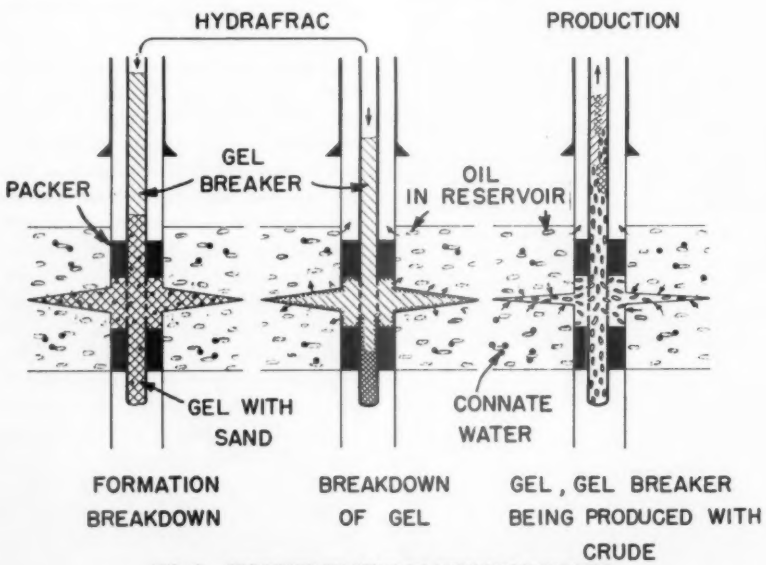

FIG. 2 — SEQUENCE OF STEPS IN HYDRAFRAC PROCESS.

Breaking of the Fracturing Fluid Viscosity: After the fracture is made, the fracturing fluid must be thin enough to flow back out of the well. The Napalm gels have the advantage of being relatively unstable, so that the viscosity of the solution will revert to approximately that of the base oil after the fracture is formed.

A further advantage of the Napalm gel is that its time of reversion to a sol is controllable within definite limits. For example, it has been found that ½% to 1% of water added to a Napalm-gasoline gel will cause reversion to a sol within 8 to 24 hours, which gives ample time for performing the Hydrafrac job. Napalm-gasoline gels will revert to sols within an hour or two if they are in quiescent contact with either salt water or many types of crudes. Furthermore, it is also possible to use solutions which will break these gels in a few minutes under quiescent contact conditions. One example is a 2% solution of petroleum sulphonates in gasoline or crude oil. This allows one to follow the Napalm gel with a second solution to insure its more rapid reversion to the sol condition.

Pump Requirements

Field experience has shown that the successful Hydrafrac treatment requires a definite fracturing of the formation, as indicated by a decrease in injection pressure; this decrease in pressure is clearly shown on several of the charts presented later.

Starting with well depth, fluid viscosity, formation thickness and permeability, and bottom hole pressure, it is possible to compute with fair accuracy, by an empirical method, the pump rate necessary to fracture a formation and to extend the fracture after it is made. It is also possible to determine the necessary fluid viscosity to fracture and to extend the fracture in the formation with a given pump rate.

Table 1 compares calculated breakdown pressures with those observed in the field. A comparison of the data presented in this table indicates a close agreement between the two figures.

Table 2 illustrates typical results of such computations. It is apparent from this table that, in formations of normal permeability, it is impossible to employ a fluid of high penetrating ability, such as the usual low-viscosity crude oil, for fracturing or extending the fracture. On sands such as in the East Texas Field, it would require a crude oil injection rate of 21 bbl/min at approximately 2,000 psi in order to fracture the formation, which is beyond practical limits, since the largest portable oilfield pumps deliver only about 3 bbl/min at this pressure. However, it is obvious from Table 2 that by using a higher viscosity material such as a 100 centipoise gel, the pump requirements are dropped to within practical limits both for fracturing and for extending the fracture.

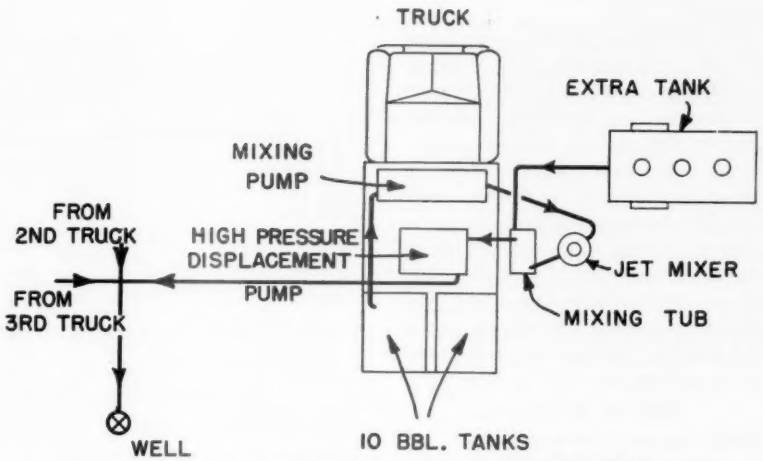

FIG. 3 — WELL HOOK-UP USING SERVICE COMPANY EQUIPMENT

TABLE 1

Calculated vs. Actual Formation Breakdown Pressures

Field	Well	Bottom hole Pressure (psi)	
		Calculated	Actual
East Texas	GA	3,000	3,350
Rangely, Colorado	EF	4,800	4,900
Hugoton, Kansas	AA	2,500	2,000
East Sasakwa, Oklahoma	FA	2,600	2,400
Frannie, Wyoming	BB	2,700	2,750

TABLE 2

Pump Rate to Fracture Hydraulically

	East Sasakwa Field Booch Sand	Hugoton Field Ft. Riley Lime	East Texas Field Woodbine Sand
Amount of open hole	35 ft.	35 ft.	20 ft.
Average formation permeability	150 md	13 md	2,000 md
Bbl/min to fracture			
Crude oil—5 centipoises	2	.13	21
Gel—100 centipoises	0.1	.007	1
Bbl/min to extend fracture to 50 ft. radius			
Crude oil—5 centipoises	11	1	213
Gel—100 centipoises	0.6	0.05	10.7
Pressure to fracture	2,100* 1,250**	1,700* 900**	2,900* 1,700**
Pressure to extend fracture	1,700* 850**	1,350* 550**	2,600* 1,400**

*Bottom hole pressure (psi) **Surface pressure (psi)

Packer Requirements

In wells where the exposed sand section is quite thick, special precautions must be taken so that the hydraulic fracturing operation can be performed at more than one depth. Ordinarily, the formation will fracture but once, and the relative increase in production due to this single fracture might be negligible in a well having a large amount of productive sand thickness. To obtain the benefits of multiple fracturing, it is necessary to set special formation packers against the wall of the hole so as to isolate sections of a few feet in thickness before applying the Hydrafrac process. This technique is also important where it is necessary to prevent the fracturing fluids from entering non-productive formations which may alternate with the producing zones exposed to the well. Packers are also required in some instances to keep the high pressures of the process from injuring pipe. Inflatable packers have been found best for this work, but due to the fact that such packers are still in the development stage, considerable mechanical difficulty has been experienced with them.

Hazards

The Hydrafrac process is accompanied by a considerable hazard to personnel. The materials usually used are inflammable and explosive, and this, together with the use of internal combustion engines, makes this process rather hazardous. It is believed, however, by exercising due caution such as covering mixing tubs and piping off engine exhausts that this process need not be more hazardous than the handling of any other inflammable liquid. The treating solutions have not ignited on any of the jobs done to date.

FIELD RESULTS

Wells Showing Sustained Increases in Production

The experimental application of the Hydrafrac process to oil and gas wells has resulted in sustained and significant increases in productivity on 11 wells out of the 23 in which it has been tried. A compilation of some of the key data obtained on these wells is shown in Table 3.

TABLE 3
Results of Hydrafrac Field Tests

Field, Well	Formation Breakdown	Sand Injection	Production			Percent Increase
			Before	After	Increase	
Hugoton (Gas) Field, Kansas (A)						
Well AA	Yes	No	769 MCF	1015 MCF	246 MCF	32*
Well AB†	Yes	Yes	53	322	269	508
Well AC†	Yes	Yes	0	258	258	Infinite
Well AD†	Yes	Yes	0	322	322	Infinite
Well AE†	Yes	Yes	0	**	—	—
Well AF†	Yes	Yes	0	**	—	—
Frannie, Wyoming (B)						
Well BA	Yes	Yes	27 BOPD	27 BOPD	0 BOPD	0
Well BB	Yes	Yes	60	160	100	167
Well BC	Yes	No	60	72	12	20
Well BD	Yes	No	65	65	0	0
Elk Basin, Wyoming (C)						
Well CA	No	Yes	0 BOPD	0 BOPD	0 BOPD	0
Winkleman Dome, Wyoming (D)						
Well DA	No	Yes	91 BOPD	91 BOPD	0 BOPD	0
Rangely, Colorado (E)						
Well EA	No	Yes	100 BOPD	65 BOPD	—35 BOPD	— 35
Well EB	No	Yes	100	100	0	0
Well EC	No	Yes	40	30	—10	— 25
Well ED	No	Yes	106	100	— 6	— 6
Well EE	No	Yes	25	25	0	0
Well EF	Yes	Yes	75	140	65	87
East Sasakwa, Oklahoma (F)						
Well FA	Yes	Yes	0 BPOD	6 BPOD	6 BOPD	Infinite
East Texas (G)						
Well GA	Yes	Yes	0 BPOD	50 BPOD	50 BOPD	Infinite
Well GB	No	Yes	4	4	0	0
Well GC	Yes	Yes	8.25	8.25	0	0
Well GD	Yes	Yes	3.5	3.5	0	0

*Combined effect of Hydrafrac and acid.
†One of four producing zones treated.
**No post-Hydrafrac production this date.

MCF—1000 cubic feet per day.
BPOD—Barrels of oil per day.

Six of these 11 successes are gas wells in the Hugoton Field; in one instance, a combination Hydrafrac-acid job was done, resulting in increasing deliverability from 53 to 439 MCF per day; an increase from 53 to 322 MCF per day was the result of the Hydrafrac treatment, with a further increase to 439 MCF per day being the result of the subsequent acid job. On a Hydrafrac treated well, the deliverability was increased from 0 to 258 MCF per day, where the average of the offset wells completed by acidization indicated an increase in deliverability from 0 to 230 MCF per day. It is not possible at this time to make a complete evaluation of the advantages or disadvantages of a Hydrafrac-acid job or of a Hydrafrac job, over an acid job alone, but a program of comparison is in progress which will involve a sufficient number of wells to arrive at a definite answer.

A much stronger case for the economic possibilities of the process is found in the five oil wells in which Hydrafrac has resulted in sustained production increases. These are as follows:

Frannie Field, Wyoming: Well BB increased from 60 to approximately 160 bbl/day and the Well BC from 60 to 72 bbl/day as the result of Hydrafrac treatment; both these increases have been sustained for over a year.

East Sasakwa Field, Oklahoma: Well FA in this field, which was producing no oil and was to be abandoned, has produced from five to six barrels per day for nine months since Hydrafrac treatment.

East Texas Field: Well GA which had produced no oil for two years produced more than 50 barrels of oil per day for several weeks while under special test after a Hydrafrac treatment, before being returned to its 20 barrels per day allowable rate. This well has been producing at the 20 barrels per day rate for five months since then, with periodic productivity tests to determine the maximum potential of the well. The last special test of this type indicated a well potential of 61 barrels of oil per day.

Rangely Field, Colorado: Well EF which was producing approximately 75 barrels of oil per day before treatment, is now producing approximately 140 barrels of oil per day as the result of Hydrafrac treatments.

Figures 4, 5, 6, and 7 show for four of the above wells, the production curve before and after treatment, and the

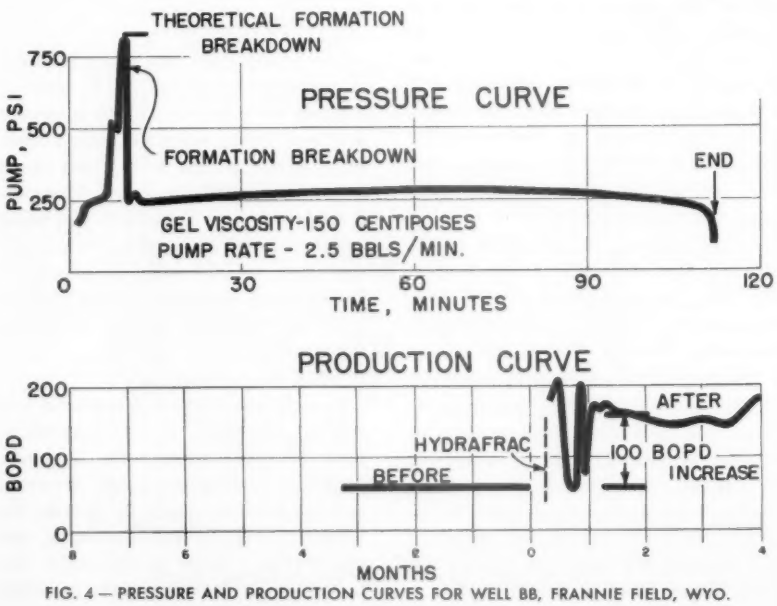

FIG. 4 — PRESSURE AND PRODUCTION CURVES FOR WELL BB, FRANNIE FIELD, WYO.

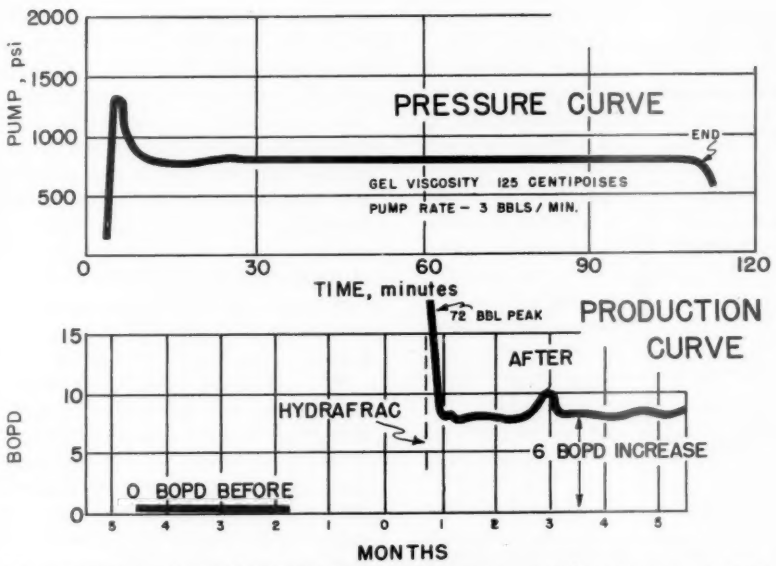

FIG. 5 — PRESSURE AND PRODUCTION CURVES FOR WELL FA, EAST SASAKWA FIELD, OKLA.

pressure curve taken during the Hydrafrac job showing the formation breakdown.

The effect on the permeability of selectively fracturing the producing formation of Well EF, Rangely Field, Colorado, is shown in Figure 8 by a comparison of permeability profiles run before and after the Hydrafrac operation. The location of each Hydrafrac job is shown between the two permeability profiles. An effort was made to have the same injection pressure for both permeability profile tests, but pump capacity prevented obtaining as high an injection pressure after Hydrafrac as was obtained before. Some of the permeable zones indicated on the "Before Hydrafrac Permeability Profile" are not evident on the "After Hydrafrac Permeability Profile" due to the lower injection pressure. However, the increase in the permeability of those sections treated as the result of hydraulically fracturing the formation is clearly evident in this figure.

Figure 9 shows the production after Hydrafrac for these five oil wells successfully treated by this process. It will be noted in all instances that a sustained increase in production was accomplished by Hydrafrac.

Well Showing No Sustained Increase in Production

No increase in production was obtained in 12 of the 23 wells treated in the preliminary experimental program. Considering the many variables involved, and the imperfections of present special packers, the proportion of failures at this stage of development is not discouraging. Both theory and field experience show that it is necessary to obtain a definite formation breakdown in order for the process to function satisfactorily. Figure 10 shows the pressure curve and the production curve of Well EC, Rangely Field, Colorado, in which the formation did not breakdown and, as expected, no increase in production was obtained.

A comparison of Well EF and Well EC in the Rangely, Colorado Field illustrates the need for the proper isolation of the desired zones to be treated. It was possible on Well EF with suitable formation packers to confine the Hydrafrac fluids to the desired zones thus fracturing the pay formation in the most prolific sections. However, on Well EC where the Hydrafrac operations were attempted without the benefit of packers, the hydraulic fracturing fluid was dispersed over the entire area of the open hole with a resulting failure to increase well production.

Production data on the 23 wells treated by Hydrafrac are shown in Table 3. It may be noted that the productivity of three of the wells treated in the Rangely Field seem to have been slightly decreased by the Hydrafrac treatment. This decrease in well production after treatment is believed to be a result of either well workovers before treatment, or normal production decline during the well testing period. For example, the pay zone in Well EA was charged with crude oil before Hydrafrac treatment during a cleanout of the hole while using crude oil as a drilling fluid, and sufficient time was not allowed for the well production to level off before the well test taken before Hydrafrac treatment. The decrease in production of Well ED after treatment represents the normal production decline for this well. Part of the production decrease of Well EC may be attributed to normal production decline; however, trouble occurred which it is believed accounted for most of this decrease.

Predictability of Results

If the engineering factors surrounding a proposed Hydrafrac job are known, experience has shown that correct prediction of success or failure of the job is usually possible. A careful review of the jobs done to date leads to the conclusion that, even with due regard to the fact that "hindsight is clearer than

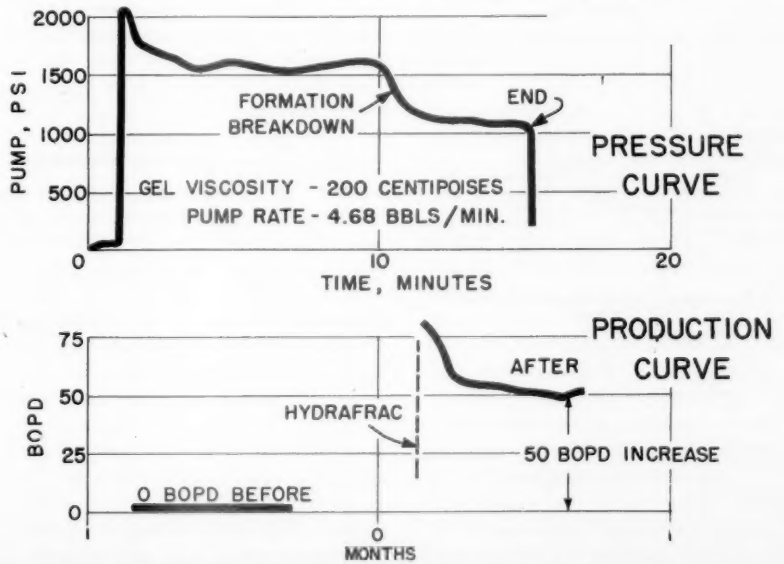

FIG. 6 — PRESSURE AND PRODUCTION CURVES FOR WELL GA, EAST TEXAS FIELD

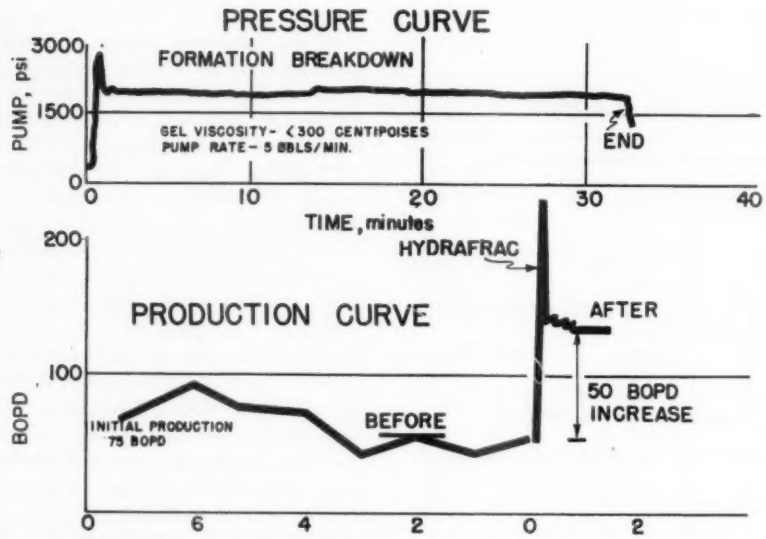

FIG. 7 — PRESSURE AND PRODUCTION CURVES FOR WELL EF, RANGELY FIELD, COLO.

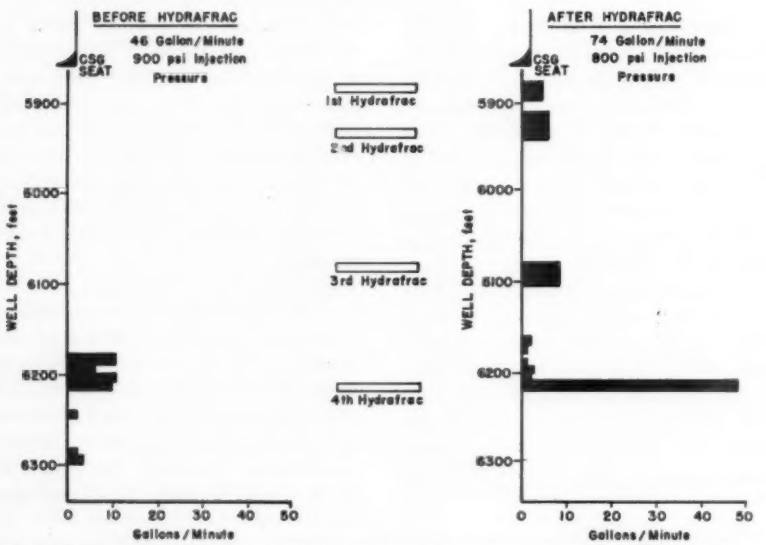

FIG. 8 — PERMEABILITY PROFILES INDICATING RESULTS OF HYDRAFRAC TREATMENT, WELL EF, RANGELY FIELD, COLO.

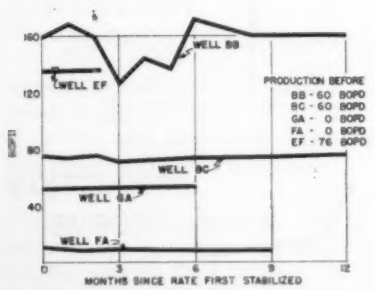

FIG. 9 — PRODUCTION AFTER SUCCESSFUL HYDRAFRAC TREATMENT.

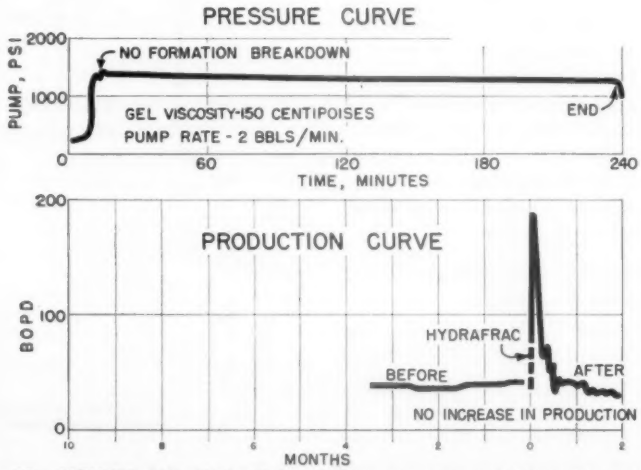

FIG. 10 — PRESSURE AND PRODUCTION CURVES, WELL EC, RANGELY FIELD, COLO.

foresight," it would have been possible to predict correctly at least 75% of the failures, and 95% of the successes, had all of the present field experience been available before each of the jobs done. As a matter of fact, many of the failures were predicted as such, and the jobs purposely done in the face of unfavorable well conditions in order to obtain research data. Incidentally, one of the treatments done under such circumstances (Well FA) was successful in spite of predicted failure.

Cost

When put into routine commercial use, the cost should be not much more than the cost of an acid job of corresponding gallonage. Where crude oil from the lease can be used as the base fluid in the Hydrafrac process, it is quite probable that the cost will be less than that for acidizing.

It is significant that the value of the additional oil and gas produced to date through the benefits of this process has already exceeded the combined cost of research, development, and all field tests.

ACKNOWLEDGMENTS

Acknowledgment is due Messrs. R. F. Farris, C. R. Fast, G. C. Howard, J. A. Stinson and other members of the staff of the Stanolind Oil and Gas Company's Research and Producing Departments for their part in the development of this process. Appreciation is expressed to the Management of Stanolind Oil and Gas Company for permission to publish this paper.

REFERENCES

1. Yuster, S. T., and Calhoun, J. C., Jr.: Pressure Parting of Formations in Water Flood Operations. *The Oil Weekly* (March 12 and March 19, 1945).

DISCUSSION

☆

By Wm. D. Owsley, Technical Adviser, Halliburton Oil Well Cementing Co., Duncan, Okla.:

I wish to highly commend Mr. Clark and his associates for this important contribution to oil production. Even at this early date in the development of this process, it is apparent that Hydrafrac can be of great value to oil producers, especially in view of the present high price of crude oil, attended by scarcity of casing and heavy increases in drilling costs. In spite of this statement, this process should not be regarded as a cure-all for any and every well.

Considerable thought has been given to the hazards attendant to the use of the Hydrafrac process. These hazards to personnel and equipment must be recognized; however, they can be minimized by simple and easily applied safety precautions. The mixing equipment can easily be arranged to prevent splash over. Precautions must be taken against leakage on all lines during the course of the job. It is suggested that this process be performed during daylight hours to reduce hazards attendant to accumulation of vapors during the night. Diesel engine powered pumping equipment offers an advantage over gasoline engine equipment in the elimination of possible fire hazards. Precautions can be taken in piping away exhaust stack gases and cooling of manifolding to prevent possible explosion.

The pumping of crude oil, diesel fuel, or gasoline, under high pressures is not considered dangerous, provided leakage in the system is prevented. There will be no occurrence of diesel effect to give explosion within the pumps or pipes unless large volumes of air be trapped within the system. Even then an intimate mixture of the vapors with air and a rapid increase in pressure to produce heat would be necessary in order to produce an explosion.

The problem of packers for segregation of short sections of open hole does offer several difficulties, and it appears that a packer design different than anything now known to be in existence is necessary. It is assumed that Hydrafrac can be applied to wells which have been gun perforated for production, in which case, the packer problem is much less difficult, since packers are already in existence which will adequately handle this condition.

There has been some thought given to difficulty with reciprocating pumps in the handling of a sand-laden fluid of the nature described. Experience in the past in handling sand of large granular size through reciprocating pumps has not been good; however, it appears that the use of thickened oil phase agents eliminates this problem.

In the use of this process, it is recommended that surface piping and manifolding to the well head be kept as simple and direct as is practical to offset line losses during rapid pumping. This will greatly assist in obtaining high injection rates into the well itself without excessive pump pressure.

While this paper presents Hydrafrac in its application to wells which have been partially depleted, it would appear that in many cases of new wells initial potential might be considerably improved by application of this process. It is believed that with proper study of all data on any well which is being considered for the use of this process, its correct application should result in a high percentage of success.

☆

By Paul E. Fitzgerald, Dowell Incorporated, Tulsa, Okla.:

Mr. Clark has presented a paper on a subject which has been discussed by petroleum engineers for years. Most engineers realize that pressure parting or formation lifting probably plays an important part in many wells where fluids are injected for various reasons. The author has furnished some valuable quantitative data bearing on this interesting phenomenon.

The pressure parting phenomenon has long been recognized in well acidizing operations. In numerous cases where the formation permeability is quite low it has been observed that the initial acidizing pressure will exceed the pressure required to lift the overburden. At pressures below this critical value the formation will take substantially no fluid but when a pressure sufficiently high to part the formation has been reached it will take fluid and the rate of fluid injection can be raised with little or no increase in the injection pressure.

After the acid enters the formation a chemical reaction takes place in which a portion of the formation is actually dissolved away thus further enlarging the previously established fracture. As the characteristics of the rock are not uniform, more rock will be dissolved by the acid in some places than in others so when the treatment is concluded the pressure parted fractures will not close but will still be open and will serve as flow channels to the well.

Mr. Clark has extended the application of the pressure parting idea by using fluids of increased viscosity and inert solid particles. These materials make the process applicable to wells having high permeability and to wells in which the producing section is not acid soluble.

☆

By C. P. Parsons, Houston, Texas:

There is considerable need for such a process.

Step 1 in the process calls for "injecting a viscous liquid, containing a propping agent, under high pressure to fracture the formation". This step is amply supported by the established practice of fracturing formations and squeezing cement and other fluids into oil sands.

Step 2 calls for "causing the viscous liquid to change from a high to a low viscosity so that it may be readily displaced from the formation". For this step there is no precedent in oil well cementing, primarily because the fluids used are viscous because of suspended solids; also because the fluids are intended to remain in the formation. Cement slurry, for instance, after injection into the fracture under high pressure increases in viscosity and changes into a plastic and finally a solid.

The second step presents the main problem in the process. The paper indicates two ways to overcome it. One way is by the use of an oil base liquid that temporarily has been made highly viscous but which will automatically revert to low viscosity after it is in place in the formation. That, of course, is the ideal answer to the problem. The other way is to follow the injection of the viscous gel with an injection of a gel-breaker. The paper does not make it clear which of the two alternatives were used in the actual field tests.

With regard to the following up with a gel-breaker, it is difficult to understand how the breaker could effectively reach out through the tightly confined thin layer of viscous gel to cause the change from high to low viscosity. It is conceivable, however, that the gel-

breaker could physically push the viscous gel ahead of it, causing the gel to spread out to a distance where the gel can no longer hold itself into a continuous ring and must disperse further in streaks, leaving openings for the gel-breaker to physically break through. The low viscosity of the breaker would permit it to come back out of the channels followed by newly released oil out of the formation. In addition, the gel-breaker, by having increased contact with the gel, would cause some of the gel to become less viscous. This would allow some of the gel to come out of the formation and thereby assist in the return of the breaker and release of oil. As to the propping agent, due to drag, it might not completely follow the viscous gel through the fracture. This could be an advantage when the gel breaker and released oil come out of the formation.

The process is a distinct contribution to the industry's important aim of increasing the productivity of oil. It is along sound, practical lines and should be encouraged and followed up with many more field tests.

☆

Author's reply to Mr. C. P. Parsons:

Mr. Parsons in his comments discussed the breaking of the fracturing fluid viscosity. He mentioned two of the methods used and asks which of these methods were used in the field experimental work.

Three methods are currently available for breaking the viscosity of the Napalm gel, any one of which we believe will do the job. These methods are:

(1) The unstable nature of the Napalm gel at bottom hole temperatures and pressures, in the presence of crude oil, will cause this gel to revert to sol in 8 to 24 hours.

(2) The addition of a small amount, ½% to 1%, water to the Napalm gel, plus the quiescent contact of this gel with salt water, will cause it to revert to sol within an hour or two.

(3) Napalm gels, when in quiescent contact with gel breakers such as petroleum sulphonates, will revert to sol in a few minutes.

Acutally in field practices all three of these methods have been used to insure complete reversion to sol of all the Napalm gel in the well, and thus to avoid the danger of plugging of the formation with the viscous oily medium.

The action of the gel breaker in the fracture filled with a viscous gel solution may be very much as Mr. Parsons describes. It is believed, however, that the quality of the Napalm gel that causes it to revert to sol on quiescent contact with petroleum sulphonates, salt water, and some type of crude oil, is the primary reason why these gels do not plug the formation.

USE OF PERMEABILITY DISTRIBUTION IN WATER FLOOD CALCULATIONS

WM. E. STILES, MEMBER AIME, CORE LABORATORIES, DALLAS, TEXAS

ABSTRACT

A method is presented for predicting the performance of water flooding operations in depleted, or nearly depleted, petroleum reservoirs. The method makes use of permeability variations and the vertical distribution of productive capacity. From these two parameters can be calculated the produced water cut versus the oil recovery. Derivations of the mathematical analogy is shown and sample calculations and curves of prediction are presented. Comparison is made of the predicted and actual performance of a typical 5-spot in an Illinois water flood.

INTRODUCTION

The use of water as a flooding medium in both depleted and "flush" oil reservoirs is gaining greater recognition and acceptance. Many of the shallower fields, depleted by primary production, have been and are being subjected to water injection in order to obtain some part of the large volume of oil remaining after primary production. Some of the earlier water flood installation proved highly discouraging and the value of water flooding was often questioned. Many of these earlier floods were haphazardly selected and developed as little was known of the physical characteristics and contents of the producing formations. The prior evaluation of the flood performance was impossible.

During the past decade the development of the required reservoir engineering tools—core analysis, reservoir fluid analysis, electric logs, fluid flow formulae, etc.—has allowed the engineer to construct and apply the methods which are presently being used to evaluate the economic and mechanical susceptibility of a reservoir to flooding.

This discussion will present a method for taking into account the effect of permeability variations in predicting the performance of water floods in depleted reservoirs.

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PERMEABILITY AND CAPACITY DISTRIBUTION

It is generally agreed by most investigators that in a single phase system fluid will flow in a porous and permeable medium in proportion to the permeability of the medium.

Producing formations are usually highly irregular in permeability, both vertically and horizontally. However, zones of higher or lower permeability are often found to exhibit lateral continuity. Thus, while structurally comparable stringers in adjacent wells may differ several fold in permeability values, they usually bear resemblance as being part of a general continuous higher or lower permeability section. It is generally agreed that where such stratification of permeability exists, injected water sweeps first the zones of higher permeability, and it is in these zones that "break-through" first occurs in the producing well. It is a basic assumption of the presently described method that penetration of a water front follows the individual permeability variations as if such variations were continuous from input to producing well. This is admittedly not rigorously true, but can be justified as making possible a simplifying mathematical approach to an otherwise extremely complicated three dimensional flow problem.

As a basis for study of the lateral flow of fluids in formations of irregular permeability, the irregularities may be conveniently represented by a permeability distribution curve and a capacity distribution curve. In obtaining these curves, the permeability values, regardless of their structural position in the formation, are rearranged in order of decreasing permeability.

If these permeability values so arranged are plotted against the cumulative thickness, a permeability distribution curve is obtained. This curve may then be likened to a "smoothed" permeability profile of the formation.

In making comparison between different distribution curves it is convenient to state the permeabilities in terms of the ratio of the actual permeability values to the average permeability of the formation. These ratios termed "dimensionless permeabilities", are used in this paper rather than the permeabilities in terms of millidarcys.

The capacity distribution curve is a plot of the cumulative capacity (starting with the highest permeabilities) versus the cumulative thickness. The capacity and thickness are given as fractions of the total capacity and thickness. Mathematically, the capacity distribution is the intergration of the permeability distribution curve.

In practice it is convenient to first obtain the capacity distribution curve and derive from it a smoothed dimensionaless permeability curve.

The method of obtaining the capacity distribution curve is illustrated in the successive column of Table 1, in which capacity and thickness are derived as fractions of their respective totals. If only a small number of permeability values are available, it is generally desirable to smooth the resultant curve. This has been done to give the capacity distribution curve shown in Figure 1.

The differentiation of the capacity distribution curve to obtain the permeability distribution curve is shown in Table 2. Here, the capacity values are read from the smoothed curve at intervals of cumulative thickness, and the increments of capacity are divided by the increments of thickness to obtain the dimensionless permeability, K′. Due to this stepwise procedure of calculation these premeability values must be plotted at the midpoints of the successive increments of thickness. The curve so obtained from these data is shown in Figure 1. The total area under the K′ curve is equal to unity.

TABLE 1

Calculation of Capacity Distribution

Cumulative Thickness; Feet	h = Fraction of Cumulative Thickness	K = Permeability; Millidarcys	ΔC = Increment of Total Capacity	C = Cumulative Capacity; Fraction
1	.0345	776	.153	.153
2	.0690	454	.089	.242
3	.1034	349	.069	.311
4	.1380	308	.061	.372
5	.1724	295	.058	.430
6	.2070	282	.056	.486
7	.2414	273	.054	.540
8	.2759	262	.052	.592
9	.3103	228	.045	.637
10	.3448	187	.037	.674
11	.3793	178	.035	.709
12	.4138	161	.032	.741
13	.4483	159	.031	.772
14	.4828	148	.029	.801
15	.5172	127	.025	.826
16	.5517	109	.021	.847
17	.5862	88	.017	.864
18	.6207	87	.017	.881
19	.6552	87	.017	.898
20	.6897	77	.015	.913
21	.7241	71	.014	.927
22	.7586	62	.012	.939
23	.7931	58	.011	.950
24	.8276	54	.011	.961
25	.8621	50	.010	.971
26	.8966	47	.009	.980
27	.9310	47	.009	.989
28	.9655	35	.007	.996
29	1.0000	16	.004	1.000
		∈ 5,075		

Derivation of Water Cut and Recovery Equations

The derivation of the water cut and the recovery equations is based on two principal assumptions: (1) fluid flow is linear and (2) the distance of penetration of the flood front is proportional to permeability.

With these assumptions, a cross section of the flood front would show penetration proportional to the permeability distribution. At the time when all permeabilities greater than a given value, K', have "broken through" to water at the producing well, a schematic diagram of the water penetration would be as shown in Figure 2.

In the diagram of Figure 2, the intake well exposed to water injection is represented by the line *ab* and the producing well by line *cd*. The rectangle *abcd* represents the floodable volume of the formation (total acre-feet of formation times the unit water flood recovery per acre-foot).

The curve *gfb* represents the water front and the enclosed area *agfba* is the permeability distribution curve. Since dimensionless permeability is used, the area under this curve is equal to unity.

Area $abcd = X+Y+Z=1$

$= \text{floodable formation} = ab \times fe = ab \times K'$

Area $agfba = W+X+Y=1$

Since the capacity distribution curve is the integration of the permeability curve, $W+X=C=$capacity corresponding to the formation thickness h and permeability K', also:

$Y=1-(W+X)=1-C$, and

$X=fe \times ac = K'h$

Areas X and Y represent the portion of the formation from which oil has been displaced by the encroaching water. The oil recovery expressed as a fraction of the total floodable formation is then:

$$\text{Recovery} = \frac{X+Y}{X+Y+Z} = \frac{K'h+(1-C)}{K'}$$

In the producing well, it has been assumed that all permeabilities greater than K' are flowing only water. The capacity flowing water is therefore C, and the capacity flowing oil is (1-C).

The water and oil production rates are calculated from these capacities by including relative permeability and viscosity terms, and in the case of oil, a formation volume factor, *u*.

$$\text{Rate of water production} = C\left(\frac{Krw}{\mu w}\right)$$

$$\text{Rate of stock tank oil production} = (1-C)\left(\frac{Kro}{\mu o}\right)\left(\frac{1}{u}\right)$$

$$\text{Rate of total fluid production} = C\left(\frac{Krw}{\mu w}\right)+\left(1-C\right)\left(\frac{Kro}{\mu o}\right)\left(\frac{1}{u}\right)$$

Thus, water cut =

$$\frac{C\left(\frac{Krw}{\mu w}\right)}{C\left(\frac{Krw}{\mu w}\right)+\left(1-C\right)\left(\frac{Kro}{\mu o}\right)\left(\frac{1}{u}\right)} = \frac{C\left(\frac{Krw}{\mu w}\cdot\frac{\mu o}{Kro}\cdot u\right)}{C\left(\frac{Krw}{\mu w}\cdot\frac{\mu o}{Kro}\cdot u\right)+\left(1-C\right)}$$

Assigning the term A to

$$\left(\frac{Krw}{\mu w}\cdot\frac{\mu o}{Kro}\cdot u\right)$$

$$\text{Water Cut} = \frac{CA}{CA+(1-C)}$$

The water cut is expressed as a fraction, the ratio of the water production rate to the total fluid production rate.

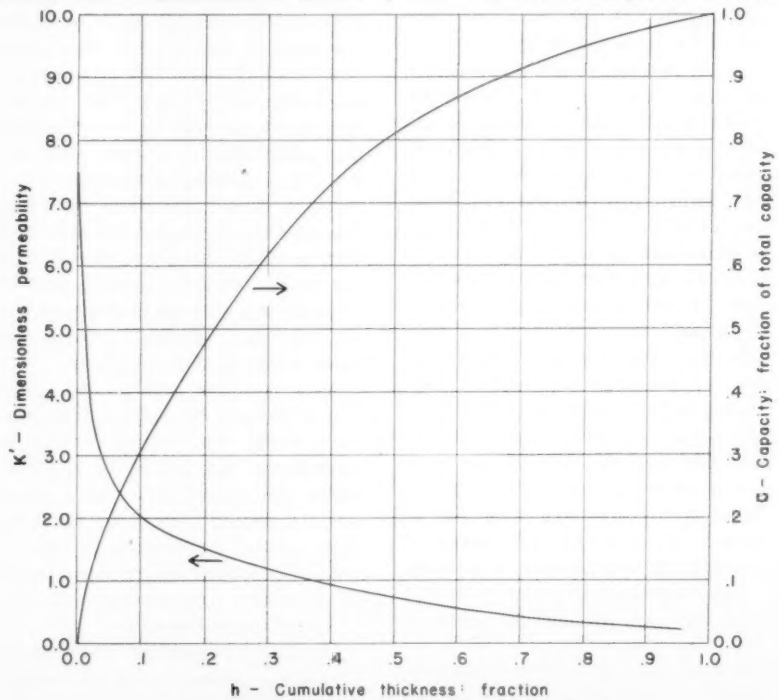

FIG. 1 — PERMEABILITY AND CAPACITY DISTRIBUTION.

TABLE 2

Calculation of Permeability Distribution

h = Fraction of Cumulative Thickness	Δh = Increment of Cumulative Thickness	C = Cumulative Capacity; Fraction	ΔC = Increment of Cumulative Capacity	$K' = \frac{\Delta C}{\Delta h}$ Dimensionless Permeability	h' = Average Cumulative Thickness Fraction
.01	.01	*.065	.065	6.50	.005
.02	.01	.110	.045	4.50	.015
.05	.03	.200	.090	3.00	.035
.10	.05	.308	.108	2.16	.075
.20	.10	.476	.168	1.68	.150
.30	.10	.620	.144	1.44	.250
.40	.10	.731	.111	1.11	.350
.50	.10	.812	.081	.81	.450
.60	.10	.870	.058	.58	.550
.70	.10	.917	.047	.47	.650
.80	.10	.952	.035	.35	.750
.90	.10	.980	.028	.28	.850
.95	.05	.991	.011	.22	.925
1.00	.05	1.000	.009	.18	.975

*From capacity distribution curve.

APPLICATION OF THE WATER CUT AND RECOVERY EQUATIONS

Sample calculations for recovery and water cut based on the previous permeability distribution data are shown stepwise in Tables No. 3 and 4.

In these tables water cut and recovery are calculated independently of each other, but as functions of the thickness *h* as a parameter.

A plot of the resultant water cut versus recovery data is shown in Figure 3.

The percentage recovery values can be converted to barrels of oil per acre foot by multiplying by the unit recovery at 100 per cent water cut and the appropriate flood coverage factor.

The unit recovery is calculated as shown in the following example:

Connate water saturation = 24 per cent of pore space.

Reservoir oil saturation (after primary depletion) = 59 per cent of pore space

Residual oil saturation after complete flushing = 21 per cent of pore space

Porosity—19 per cent

Formation Volume Factor = 1.073 barrels/barrel

Unit Recovery =

$$7758\ (.19)\left(\frac{.59-1.073(.21)}{1.073}\right) =$$

501 barrels of stock tank oil per acre foot

The total liquid saturation in this example is the sum of the 59 per cent oil saturation and the 24 per cent water saturation, or 83 per cent. The remaining 17 percent of pore space is occupied by the free gas remaining after primary depletion.

In order to increase reservoir pressure sufficiently to attain the desired production rate it is necessary to compress this gas space with injected water.

RECOVERY EQUATION—

$$\text{Recovery} = \frac{X+Y}{X+Y+Z} = \frac{K'h+(1-C)}{K'} \qquad (1)$$

WATER CUT EQUATION—

$$\text{Water Cut} = \frac{(W+X)\left(\frac{K_{rw}}{\mu_w}\cdot\frac{\mu_o}{K_{ro}}\cdot u\right)}{(W+X)\left(\frac{K_{rw}}{\mu_w}\cdot\frac{\mu_o}{K_{ro}}\cdot u\right)+\left(1-(W+X)\right)}$$

since $W+X=C$, and $\left(\frac{K_{rw}}{\mu_w}\cdot\frac{\mu_o}{K_{ro}}\cdot u\right)$ = constant = A

$$\text{Water Cut} = \frac{C\cdot A}{C\cdot A+(1-C)} \qquad (2)$$

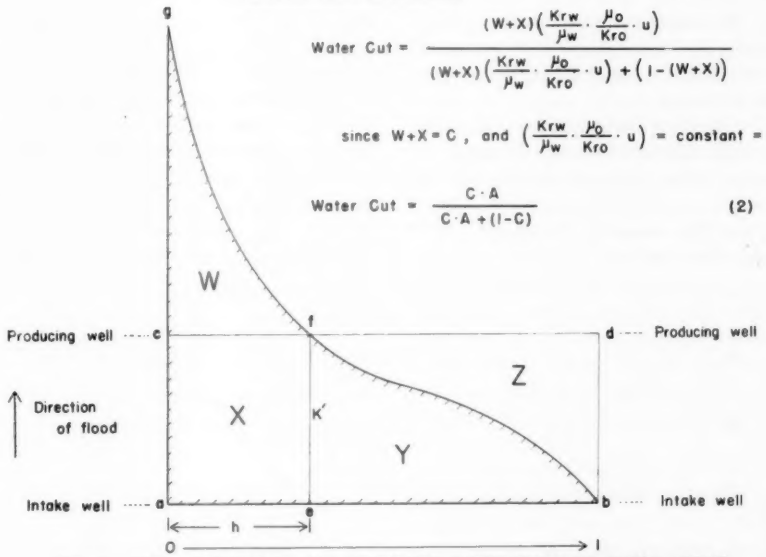

FIG. 2 — BASIC EQUATIONS AND SCHEMATIC ILLUSTRATION OF FLOOD FRONT.

TABLE 3

Calculation of Recovery

h = Fraction of Cumulative Thickness	K' = Dimensionless Permeability	C = Cumulative Capacity; Fraction	K'h	K'h+(1-C)	$\frac{(K'h+(1-C))}{K'} = \text{Recovery}$ Fraction of Total Recovery
.00	*7.50	*.000	.000	1.000	.133
.01	5.32	.065	.053	.988	.186
.02	3.83	.110	.076	.966	.252
.05	2.69	.200	.135	.935	.348
.10	2.03	.308	.203	.895	.441
.20	1.55	.476	.310	.834	.538
.30	1.19	.620	.357	.737	.619
.40	.92	.731	.368	.637	.692
.50	.71	.812	.355	.543	.765
.60	.55	.870	.330	.460	.836
.70	.41	.917	.287	.370	.902
.80	.31	.952	.248	.296	.955
.90	.25	.980	.225	.245	.980
.95	.20	.991	.190	.199	.995
1.00	.00	1.000	0.000	0.000	1.000

*From permeability and capacity distribution curves.

Since reservoir pressure is built up as this gas is compressed, a "kick" in production rate is obtained somewhat before an amount of water equivalent to the gas space has been injected. However, for purposes of predictions the volume of water required to fill up is generally assumed equal to this gas space.

For example, using the above 17 per cent gas space, a 5-spot unit pattern containing 100 acre feet of formation and a porosity of 19 per cent or 1474 barrels per acre foot, the amount of water required for fill up is 100 (1474x.17), or 25,000 barrels. The time required at an injection rate of

100 barrels per day per 5-spot is, therefore, 250 days.

It should be noted that thus far the calculations have not included a flood coverage factor which even under the most favorable conditions may limit the actual recovery to some 70 to 90 per cent of the calculated maximum value at 100 per cent water cut. (The term "water cut", as used in the text, is intended to be synonymous with the phrase "water per cent by volume".) The flood coverage factor may be estimated from experience or electrical model studies.

After the flood coverage factor and the unit recovery to 100 per cent water cut have been determined they may be applied to the previously obtained water cut versus recovery data to convert to recovery in terms of barrels. These data and the assumed water injection rate furnish the necessary information for determining the time behavior of the flood unit. Illustrated in Table 5 are the stepwise calculations for determining the cumulative oil recovery, oil rate, and cumulative water injected versus time.

From these basic results and other derived information, such as total injection water requirements and time to reach economic limit, can be determined the economic feasibility of a water flood project.

TABLE 4

Calculation of Water Cut

h = Fraction of Cumulative Thickness	C = Cumulative Capacity; Fraction	C*A[1]	C*A+(1-C)	$\frac{C*A}{C*A+(1-C)}$ = Water cut Fraction
.00	*.000	.000	1.000	—
.01	.065	.092	1.027	.090
.02	.110	.156	1.046	.149
.05	.200	.284	1.084	.262
.10	.308	.437	1.129	.387
.20	.476	.676	1.200	.563
.30	.620	.880	1.260	.698
.40	.731	1.038	1.307	.794
.50	.812	1.153	1.341	.860
.60	.870	1.235	1.365	.905
.70	.917	1.302	1.385	.941
.80	.852	1.352	1.400	.966
.90	.980	1.392	1.412	.986
.95	.991	1.408	1.417	.994
1.00	1.000	1.420	1.420	1.000

*From capacity distribution curve.

$$^{1}A = \frac{Krw}{Kro} \times \frac{\mu o}{\mu w} \times Q = \frac{.20}{.80} \times \frac{4.34}{..82} \times 1.073 = 1.42$$

COMPARISON OF ACTUAL AND PREDICTED BEHAVIOR

The presently described method of taking into account the variations in permeability has been used in a number of engineering studies of water flood projects. Figure 4 shows a comparison of the predicted and the actual recovery versus water cut relationship in one of these earlier projects which has now progressed sufficiently to make possible such comparison. The behavior of this project, a Benoist Sand flood in Illinois, was calculated by the above method prior to the start of injection.

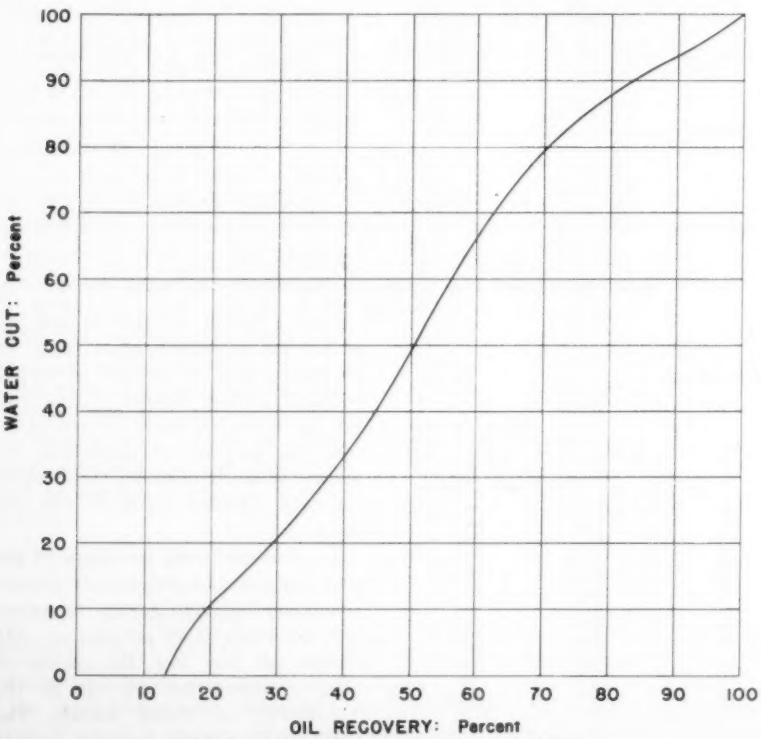

FIG. 3 — CALCULATED WATER CUT VS. RECOVERY

LIMITATIONS

The limitations of the above method of calculating water flood behavior should be pointed out. In particular, this method should not be applied where there is present a gas zone or water zone immediately above or below the oil zone under consideration. In this event there would be by-passing of the oil zone by injected water, or there would be coning and the oil recovery to any given water cut would be less than the calculated recovery. However, in the case of gas or water zones of known permeability certain modifications can be made in the basic equations to adjust for those conditions.

The water cut recovery curve should not be interpreted as a prediction of the behavior of any individual well, since structural consideration may make individual recoveries greater or less than the calculated value. Instead, the water cut recovery curve must be considered an average relationship for an entire field assuming a uniformly spaced flood is established therein. The water cut-recovery relationships should be based on the permeability and capacity distribution of a large number of permeability measurements from many wells in the area to be flooded.

This method does not take into account all factors which may influence the production history, such as the presence of gas or water zones, distance from fluid contacts, rate of production, structural position of the individual wells, lateral versus upward encroachment, shape of field, spacing pattern effect, etc. As more data and experience is obtained the effect of these factors will be better understood. In

TABLE 5

Predicted Performance of 5-Spot at 100 Bbls/Day Injection Rate

Cumulative Recovery; Fraction of Total	Cumulative Recovery; Barrels	Δ Recovery; Barrels	Water cut; Fraction	Average Water cut; Fraction	Average Oil Rate; bbls/day = 1e0(1-W)	Days to Produce Δ Recovery at Average Oil Rate	Cumulative Days after Fill-up	Cumulative Water Injected; Barrels
.000	*0	——	.000	.000	100.0	——	0.0	25,100 (fill-up)
.133	5,664	5,664	.000	.000	100.0	56.6	56.6	30,760
.200	8,517	2,853	.102	.051	94.9	30.1	86.7	33,770
.250	10,646	2,129	.147	.125	87.5	24.3	111.0	36,200
.300	12,776	2,130	.204	.176	82.4	25.8	136.8	38,780
.350	14,905	2,129	.264	.234	76.6	27.8	164.6	41,560
.400	17,034	2,129	.328	.296	70.4	30.2	194.8	44,580
.450	19,163	2,129	.397	.363	63.7	33.4	228.2	47,920
.500	21,293	2,130	.485	.441	55.9	38.1	266.3	51,730
.600	25,551	4,258	.667	.576	42.4	100.4	366.7	61,770
.700	29,810	4,259	.799	.733	26.7	159.5	526.2	77,720
.800	34,068	4,258	.882	.841	15.9	267.8	794.0	104,500
.850	36,197	2,129	.911	.897	10.3	206.7	1,000.7	125,170
.900	38,327	2,130	.938	.925	7.5	284.0	1,284.7	153,570
.950	40,456	2,129	.964	.951	4.9	434.5	1,719.2	197,020
.970	41,307	851	.977	.970	3.0	283.7	2,002.9	225,390
.990	42,159	852	.991	.984	1.6	532.5	2,535.4	278,640

*Total recoverable oil in 5-spot = 100 acre-feet × 501 bbls/ac-ft. × 85% coverage = 42,585 bbls.

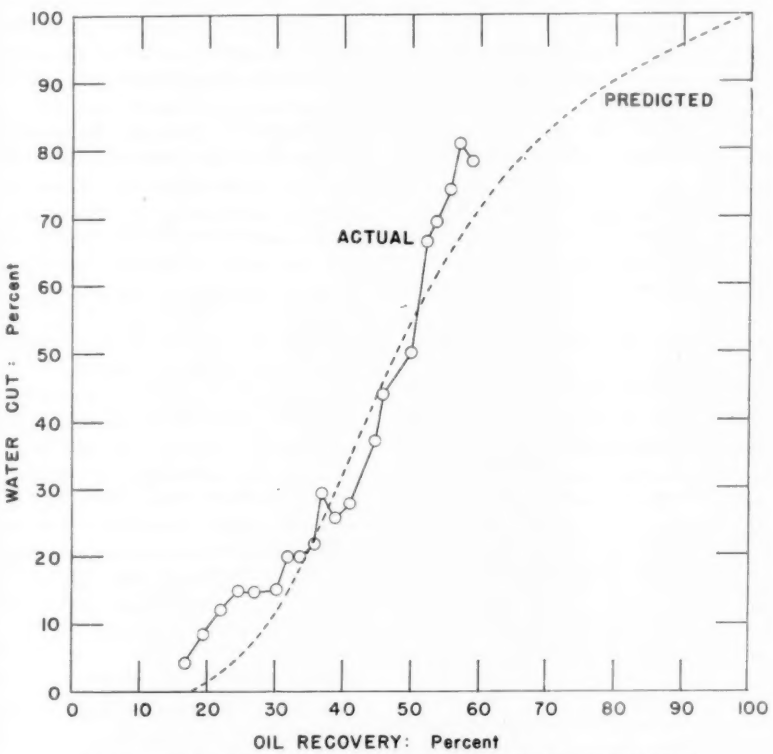

FIG. 4 — COMPARISON OF PREDICTED AND ACTUAL FLOOD PERFORMANCE.

the meanwhile the method herein presented must be considered an approach towards a mathematical treatment of the effect of permeability distribution in water flood performance.

SUMMARY

It has been shown that permeability variations in a reservoir may be represented by a permeability distribution curve and a capacity distribution curve.

Equations have been derived to incorporate mathematically the effect of the permeability distribution in the calculation of water flood recoveries.

Examples are presented to show the application of the equations to predictions of water flood performance in a depleted reservoir; however, the method may be applied to studies in "flush" fields.

A comparison of predicted and actual water cut-recovery relationship is shown.

Certain limitations of the method are presented and it is pointed out that the method is essentially an approximation intended to take into account principally the distribution of permeability in a reservoir.

ACKNOWLEDGMENT

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T. P. 2512

RELATIONSHIP OF DRILLING MUD RESISTIVITY TO MUD FILTRATE RESISTIVITY

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ABSTRACT

The effect of suspended solids on the resistivity of slurries is discussed and the relationship between drilling mud resistivity and mud filtrate investigated. It is concluded that it is erroneous to substitute mud resistivity for mud filtrate resistivity in electric log calculations. A recommendation is made that both the bud resistivity and the mud filtrate resistivity be determined when electric logs are run.

INTRODUCTION

The electric log is influenced not only by the resistvity of the drilling mud in the borehole at the time of logging but also by the resistivity of the drilling mud filtrate.

Sherborne and Newton[1] investigated the relationship of mud resistivity to mud filtrate resistivity and concluded that, "The resistivity of the mud in most cases closely approximates that of its filtrate," and "In fact, with the exception of Aquagel and its filtrate, the figures for any particular mud and filtrate are almost identical." Present practice is to determine only the drilling mud resistivity and apply this same value to calculations involving the mud filtrate.[2] The purpose of this study is to reexamine the factors governing the relationship between mud resistivity and mud filtrate resistivity.

EFFECT OF BOREHOLE FLUID ON THE ELECTRIC LOG

Resistivity Log

The resistivity log may be modified by the resistivity of the borehole fluid in two different ways:

(1) The apparent resistivity of a formation may be different from the true resistivity of the formation because of the flow of some current through the drilling mud in the borehole. Therefore the resistivity of the mud is an important factor.

(2) The apparent resistivity may differ from the true resistivity, if a formation is invaded by mud filtrate, because of displacement by the mud filtrate of some of the interstitial fluid in the formation. In this case the resistivity of the mud filtrate rather than the resistivity of the mud is the important factor.

Self Potential Log

The self potential arises, in part, from electrochemical effects resulting from the interaction of connate waters in porous formations and the fluid in the borehole. Expressed in simple form,

$$E = K \log \frac{\rho 1}{\rho 2}$$

where E is the electrochemical self potential, K is a derived constant, $\rho 1$ is the resistivity of the borehole fluid, and $\rho 2$ the resistivity of the water in the formation. A theory of the electrochemical component of the self potential in boreholes has been recently set forth by Wyllie.[3] In the above equation resistivities have been substituted for activities of the ions in the fluids.[4] It is therefore apparent that the resistivity of the mud filtrate is more nearly representative of the activities of the ions than is the resistivity of the mud. However, it is possible that in some instances the ionic activities of cations from certain clays may contribute to the total cationic activity of the drilling fluid to such an extent that the mud resistivity is more nearly representative of the activities than the filtrate resistivity. This is particularly the case when the resistivity of the mud is less than the resistivity of the mud filtrate.

In addition the apparent self potential may be influenced by the resistivity of the drilling mud because of current flow through the borehole.

RESISTIVITY OF SLURRIES

Aqueous drilling muds are slurries containing fine-grained solid particles. The solid constituents consist mainly of added clays and weighting materials in addition to solids contributed by the drilled formations. The filtrate is primarily water in which quantities of salts or other chemicals are dissolved. The resistivity of the fiiltrate is a function of the type and quantity of dissolved material whereas the resistivity of the mud is a function of the combined resistivities of the filtrate and the resistivities of the suspended solids.

Experiments have been carried out to determine the relationship between the resistivity of solutions and the quantity and type of solid matter insuspension. Solid materials of high resistivity, as well as solid materials of relatively low resistivity, have been used. The data obtained make possible the evaluation of the probable effect of suspended solids on the resistivity of drilling mud.

Procedure

Resistivities were determined by means of a conventional conductivity cell with platinized-platinum electrodes. Total resistance between the electrodes was measured by Kohlrausch's alternating current bridge method using a General Radio Company Type 650-A impedance bridge with telephone. The cell was standardized with potassium chloride solutions of known normalities in order to calibrate the cell so that measured resistances of slurries could be converted to resistivities.

Resistivities were determined for mixtures of potassium chloride solution and solid materials by placing a measured quantity of solution in the cell and adding weighed quantities of solid materials in small increments to the solution. The net change in resistance on addition of solid materials was measured. Even distribution of the solid particles was maintained within the cell by a motor-driven glass propeller before measurements were made.

Slurries Containing High-Resistivity Solids

Powdered silica sand having a maximum diameter of about 60 microns and precipitated chalk of commercial grade were used to make the slurries whose resistivities were measured. Both of these substances have high resistivities, are virtually insoluble, and effectively do not carry current in a slurry. The resistivities of slurries composed of potassium chloride solution and these two solid materials are given in Table 1.

The ratio of the resistivity of the solution to the resistivity of the slurries was computed and was found to follow the relationship established by Archie[5]

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[1] References are at the end of the paper.

for fluid-saturated rocks with intergranular porosity, i.e.:

$$\frac{\text{Resistivity of rock sat. with water}}{\text{Resistivity of water}} = \frac{1}{(\text{Porosity})^m}$$

Since, for slurries, percent fluid by volume is analogous to porosity, this same relationship can be expressed by inversion as:

$$\frac{\text{Resistivity of water}}{\text{Resistivity of slurry}} = (\text{Percent fluid})^m$$

The value of the factor m for slurries of powdered silica and precipitated chalk was found to be consistently close to 1.6, which is higher than the value of 1.3 computed for packed uniform spheres.[6] This higher value may be attributed to the fact that the powdered materials are unsorted and non-spherical in shape.

Additional experiments were made using fine steel shot and rounded Ottawa sand of uniform size. The steel shot were covered with a resistant oxide film so that they were non-conductive. The factor m for these materials was calculated to be 1.22 which is slightly less than the theoretical value of 1.3 for packed uniform spheres.

A sample of well sorted, angular quartz sand was found to give a value of m equal to 1.39.

TABLE 1

Measured Resistivities of Slurries

Volume of Fluid (percent) P	Resistivity of Slurry at 82.4° F. (ohm-meters)	Resistivity of Water / Resistivity of Slurry	Factor m
	Powdered Silica Sand		
100.0	0.184	1.00	1.00
98.2	0.195	0.94	3.12
94.1	0.195	0.94	0.96
93.7	0.231	0.89	1.81
92.3	0.208	0.85	2.01
89.3	0.223	0.83	1.68
89.0	0.209	0.85	1.35
84.7	0.246	0.75	1.72
81.5	0.256	0.72	1.59
80.0	0.262	0.71	1.58
74.0	0.296	0.63	1.57
70.8	0.318	0.58	1.59
65.4	0.348	0.53	1.50
64.3	0.365	0.51	1.55
61.2	0.432	0.43	1.74
57.8	0.424	0.43	1.52
57.5	0.457	0.40	1.64
56.0	0.454	0.41	1.56
53.7	0.501	0.37	1.61
50.0	0.596	0.31	1.70
46.6	0.668	0.27	1.69
45.6	0.680	0.27	1.68
44.8	0.674	0.27	1.61
44.4	0.710	0.26	1.66
	Precipated Chalk		
100.0	0.184	1.00	1.00
95.0	0.198	0.93	1.32
92.5	0.202	0.91	1.34
92.5	0.209	0.88	1.68
90.0	0.209	0.88	1.38
86.3	0.228	0.81	1.46
85.1	0.248	0.74	1.86
82.2	0.262	0.70	1.83
79.0	0.268	0.69	1.58
77.5	0.290	0.63	1.77
74.4	0.307	0.60	1.73
70.7	0.318	0.58	1.58
67.5	0.348	0.53	1.62
67.1	0.368	0.50	1.73
65.2	0.374	0.49	1.67
100.0	0.151	1.00	1.00
93.5	0.167	0.90	1.55
85.6	0.195	0.77	1.69
79.6	0.228	0.66	1.83
72.8	0.253	0.60	1.63
69.1	0.267	0.57	1.56

Slurries Containing Low-Resistivity Solids

The relationship derived for slurries containing solids of high resistivity does not hold for drilling muds. Certain solid materials contained in drilling muds, notably Aquagel, have a low effective resistance since some clays may partially dissociate in water and conduct current as true electrolytes. This property of clays has been extensively investigated by Marshall.[7]

The relationship of Aquagel mud to the resistivity of the mud filtrate for muds of different resistivities is given in Table 2. These figures have been calculated from data given by Sherborne and Newton[1] and are supplemented by determinations made by the writer. These data indicate that when the filtrate has a relatively high resistivity, the clay particles may be more conductive than the filtrate, thus giving a lower resistivity for the mud than for the mud filtrate. When the resistivity of the filtrate is relatively low, the resistivity of the mud may be appreciably greater than the resistivity of the filtrate because the particles are less conductive than the fluid in which they are suspended. This is analogous to the relationship of the individual resistances of two resistors to their total resistance when in parallel.

Drilling Muds

The composition of drilling muds may be complex. Composition not only varies from well to well but may alter considerably during the drilling of a well. The suspended particles may consist of both resistant particles and conductive clays. The over-all effect of the suspended resistant solids is to increase the mud resistivity relative to the mud filtrate. The effect of the suspended clays may be conversely to decrease the mud resistivity. The combined effect of the two types of solids may be either to increase or decrease the resistivity of the mud, depending on the relative effective conductivities of the suspended clay and the filtrate. Because of these uncertainties, it is impractical to determine the resistivity of the mud filtrate from the mud resistivity.

The resistivity of a drilling mud is usually greater than the resistivity of the mud filtrate. The ratio of mud filtrate resistivity to mud resistivity for several muds is given in Table 3. The first five examples are summarized from data on modified muds taken from the paper by Sherborne and Newton.[1] The others are measurements made on muds from four different wells of the Gulf companies. The ratio of mud filtrate resistivity to mud resistivity for all determinations varies from 1.5 to 0.66.

TABLE 2

Relationship of Filtrate Resistivity to Resistivity of Aquagel Mud

Resistivity at 80° F. (ohm-meters)		Filtrate Resistivity
Mud	Filtrate	Mud Resistivity
7.6	10.2	1.34
6.9*	10.5	1.52
4.9	6.0	1.22
3.3	3.9	1.18
2.4	2.4	1.00
1.4	1.3	0.93
0.80*	0.70	0.88
0.71	0.56	0.79

* These two determinations were made by the writer. Other data taken from Sherborne and Newton.[1]

TABLE 3

Relationship of Filtrate Resistivity to Resistivity of Some Drilling Muds

Mud	Number of Determinations	Filtrate Resistivity / Mud Resistivity	
		Range	Average
Mojave*	20	1.00–0.70	0.84
Wilmington Slough	24	1.00–0.81	0.90
Aquagel*	42	1.30–0.79	1.16
McKittrick*	40	1.00–0.73	0.83
Oxo*	44	1.56–0.80	0.95
Well A	9	1.04–0.81	0.99
Well B	14	1.24–0.69	0.80
Well C	14	0.94–0.66	0.78
Well D	3	0.85–0.82	0.84

* Calculated from data taken from paper by Sherborne and Newton.[1]

CONCLUSIONS

1. The relationship between the resistivities of a series of slurries composed of fine-grained particles of high resistance and the resistivity of the suspending fluid has been found experimentally to satisfy the equation:

$$\frac{\text{Resistivity of water}}{\text{Resistivity of slurry}} = (\text{Percent fluid})^m$$

where m is a constant.

2. A slurry made with a clay such as Aquagel may have a higher or a lower resistivity than the mud filtrate, depending on the effective relative resistances of the suspended clay and the fluid it displaces.

3. The resistivity of a drilling mud filtrate is usually appreciably less than the resistivity of the mud but may be the same or greater. The ratio of mud filtrate resistivity to mud resistivity has been found experimentally to range from 1.5 to 0.66.

4. In making quantitative calculations from electric log data it is erroneous to assume that the mud filtrate resistivity is the same as the mud resistivity. It is therefore essential that both mud resistivity and mud filtrate resistivity be determined at a specified temperature when electric logs are run.

ACKNOWLEDGMENTS

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A QUANTITATIVE ANALYSIS OF THE ELECTROCHEMICAL COMPONENT OF THE S. P. CURVE

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ABSTRACT

The relationship between the electromotive force (E.M.F.) across a shale barrier and the concentrations of sodium chloride solutions on either side has been investigated.

It is shown that the action of a shale barrier is analogous to a glass membrane separating two acid solutions of different hydrogen ion concentrations. The shale behaves as a sodium electrode and is responsive to the activities of the sodium ions in the two solutions in such a way that the potential can be calculated by means of the Nernst equation. This conclusion is confirmed by laboratory experiments.

In a borehole the total E.M.F. of a shale cell is the algebraic sum of the potential across the shale and a boundary potential. The relationship between total E.M.F. and the resistivity ratio of two sodium chloride solutions is indicated for a number of formation temperatures. The E.M.F. thus predicted is then compared with the self potential read from an electric log and good agreement is demonstrated.

Based on both the self potential and resistivity curves of the electrical log, a method is given for calculating connate water content in a bed having intergranular porosity and containing both connate water and hydrocarbons.

INTRODUCTION

The first paper on electrical well logging by C. and M. Schlumberger and E. G. Leonardon in 1934[1] attributed the self potential curve principally to streaming potentials, i.e. to electrokinetic effects. Almost immediately great difficulties were encountered in reconciling many of the curves they obtained with this interpretation, and a second paper[2] by the same authors soon appeared. In this second paper self potentials were attributed to the combined effects of streaming potentials and electrochemical potentials, the electrochemical potential being considered the result mainly of the interaction of fluids of differing salt concentrations, i.e. a boundary potential, and partly of potentials set up at the faces of impermeable materials. Some experiments involving a gray clay for the impermeable material were quated. The Schlumbergers and Leonardon deduced from the equation for a simple boundary potential that the electrochemical potential, as opposed to the electrokinetic potential, could be expressed in the form

$$E = K \log \frac{\rho_m}{\rho_c} \quad \text{- - - - - - - - 1}$$

where K is a constant, ρ_m the mud resistivity, ρ_c the resistivity of the connate water in a porous bed. However, no general expression for the constant K was obtained.

Although the literature between 1934 and 1943 contains a number of quotations of their results, the valuable work of the Schlumbergers and Leonardon was not extended so that the electrochemical potential has been generally attributed wholly to boundary potentials between the mud in the borehole and the connate waters in porous formations. Unfortunately, however, the fundamental premise of all these papers, that a boundary potential can give rise to current flow in a borehole, is thermodynamically untenable. As will be shown, the fact that the electrochemical potential can be fairly accurately express as $E = K \log \rho_m/\rho_c$, a form in which a boundary potential may also be written, is partly fortuitous. The boundary potential is indeed an integral part of the expression for the electrochemical potential in a borehole, but in magnitude it represents only about 20% of the total potential.

In 1943 an important step in the elucidation of electrochemical potentials was made by Mounce and Rust[3] who showed that if a wall of shale separated two compartments which contained saline solutions of different concentrations, and if the two solutions were themselves brought into contact in the pores of a porous inert membrane (such as unglazed porcelain) a current flowed through the shale and saline solutions. The direction of positive current was from the shale into the more dilute solution. The paper of Mounce and Rust, while repeating some of the observations of the Schlumbergers and Leonardon, seems to be the first to show that the shale was the seat of a genuine electrochemical effect capable of causing current flow. In the same paper Mounce and Rust pointed out the similarity between the fundamental conditions of their experiment and the conditions which existed when a bed of shale in the ground was simultaneously in contact with a porous sand containing saline connate water and mud fluid of salinity different from that of the water in the sand.

Since it is now generally recognized that the S.P. curve measures ohmic potential changes in the mud fluid in the well bore resulting from changes in current flow, it is apparent that currents having their origin in the electrochemical interaction of mud filtrate and connate waters with shale beds are a very important portion of the total S.P. The work of Mounce and Rust[3] and others appears to indicate that, in general, the electrochemical portion of a particular kick on a S.P. curve far exceeds any electrokinetic potentials resulting either from streaming potentials or Dorn effects. The Dorn effect, or sedimentation potential, arises when small particles are allowed to fall through certain fluids under the influence of gravity, a difference of potential being observed between two electrodes placed at different levels in the stream of falling particles. The Dorn effect is unlikely to affect seriously the S.P. curve as now measured.

A successful analysis of the electrochemical aspects of the S.P. log should

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[1] References are given at the end of the paper.

thus give information of a very wide applicability to electrical log interpretation. Such an analysis, supported by a number of laboratory and field results, is attempted below.

Theoretical Analysis of the Shale Cell

The primary measurement which can be made from a conventional S.P. electrical log curve is the potential difference between points in the borehole opposite a porous formation and points opposite a shale formation, i.e. the amplitude of a S.P. peak above the shale base line. For the purpose of this analysis the porous and shale formations will both be considered thick and of fairly low resistivity, since decrease in bed thicknesses or high bed resistivities will markedly reduce the magnitude of the potential difference recorded on the log. This aspect of the S.P. curve problem has recently been admirably discussed by Doll[4] who also pointed out that if V is the recorded potential difference on the S.P. curve, and E the total theoretical E.M.F. giving rise to current flow, V will be sensibly equal to E under the conditions set forth above.

Although the nature of the metal is theoretically immaterial, lead electrodes are customarily used in the practical logging device. The cell whose true E.M.F., E, is being measured appears to be the following:

Lead/Mud//Interstitial water in the porous bed/Shale/Mud/Lead.

Here, following the normal electrochemical practice, the cell is written so that the direction of positive current flow within the cell is from left to right, i.e. the right-hand lead electrode is the positive pole of the cell. Single oblique lines represent boundaries between solid and liquid phases and double oblique lines a liquid junction between two solutions. Assuming that the potential difference at each lead/mud interface is the same (which implies that the electrodes have come to equilibrium with the mud fluid, that they are not being scratched, and that no significant differences in the composition of the mud surrounding the two electrodes exist), these potential differences are opposed in direction and hence cancel each other. Thus the net E.M.F. of the shale cell may be considered to be:

Mud//Interstitial water in the porous bed/Shale/Mud.

This net E.M.F. is composed of the algebraic sum of two potentials, namely a boundary potential at the mud// interstitial water in the porous bed interface, and an E.M.F. between the interstitial water and the mud across the shale. The E.M.F. across the shale has been shown by Mounce and Rust to give rise to a sustained current flow. The quantitative aspects of the generation of this E.M.F. will be considered below. The boundary potential at the interface of the porous bed and mud fluid is, however, a better known phenomenon and will be considered first. For the purpose of this discussion the principal electrolyte in the waters comprising the borehole mud and the interstitial water in the porous bed is presumed to be sodium chloride.

A boundary potential results from the separation of electrical charge which occurs at the interface of two saline solutions of different concentrations when the speeds of migration of the positive and negative ions composing the salts are dissimilar. In sodium chloride solutions the negative chloride ion diffuses more rapidly than the positive sodium ion. Since at an interface of sodium chloride solutions of different concentration the sodium chloride will diffuse from the region of high to low concntration, as electrical double layer tends to be set up at the interface such that the low concentration side of the interface is negative and the high concentration side positive. The initial separation of electrical charges does not increase since the negative ions which diffuse across the boundary are attracted back by the positive ions left behind, and diffusion of one salt solution into the other can only occur by diffusion of both positive and negative ions together. Thus at the boundary there is no sharp change in concentration, but the potential difference between the bulk of one solution and the other tends to remain fairly constant. Technically the type of boundary formed by the mud//interstitial water interface in a porous material would be of the "constrained diffusion" type since mixing of the two solutions by diffusion would be slow.

The general expression for a boundary potential between salts of different types and valencies as given by Henderson[5] is, for dilute solutions:

$$E_b = \frac{RT}{F}\left(\frac{(U_1 - V_1) - (U_2 - V_2)}{(U_1 + V_1) - (U_2 + V_2)}\right) \ln \frac{U'_1 + V'_1}{U'_2 + V'_2} \quad \cdots 2$$

where U_1, V_1, etc. are defined as:

$U_1 \equiv \Sigma\,(c_+ u_+)_1$ $\quad V_1 \equiv \Sigma\,(c\,v_-)_1$

$U'_1 \equiv \Sigma\,(c_+ u_+ z_+)_1$ $\quad V'_1 \equiv \Sigma\,(c_- v_- z_-)_1$

and where c_+ and c_- are the concentrations of cations an danions respectively, u_+ and v_- are the corresponding ionic mobilities and z_+ and z_- are their valencies. The suffix 1 refers to the ions in solution 1 and similar expressions hold for U_2, V_2, etc. in which the ions in solution 2 are concerned. R is the gas constant, F the Faraday, T the absolute temperature.

For dilute solutions of monovalent salts of different concentration this reduces to:

$$E_b = \frac{RT}{zF}\left(\frac{v-u}{v+u}\right) \ln \frac{c_1}{c_2} \quad \cdots\cdots 3$$

where c_1 and c_2 are the concentrations of the two solutions. For monovalent ions such as sodium and chloride z is 1.

More accurately the concentrations should be replaced by the mean activities[6] of the electrolytes in the two solutions when,

$$E_b = \frac{RT}{zF}\left(\frac{v-u}{v+u}\right) \ln \frac{a_1}{a_2} \quad \cdots\cdots 4$$

where a_1 and a_2 are the mean activities of the electrolytes in the two solutions.

For sodium chloride solutions at 25° C. the numerical expression of this relationship is:

$$E_b = 11.5 \log \frac{a_1}{a_2} \text{ millivolts} \quad \cdots 5$$

The determination of the mean activities demanded by equations 4 and 5 is possible. It is, however, more convenient to replace the ratio of the activities of the electrolytes in the solutions by the ratio of the conductivities of the two solutions. Although the relationship between conductivity and activity ratios becomes less accurate at higher concentrations, this approximation is permissible for dilute solutions. From the standpoint of electrical logging techniques this may be more familiarly expressed as a resistivity ratio, and equation 5 becomes:

$$E_b = 11.5 \log \frac{\rho_{mf}}{\rho_c} \text{ millivolts} \quad \cdots 6$$

where ρ_{mf} is the resistivity of the mud filtrate derived from a mud composed solely of an aqueous sodium chloride solution and inert solid materials in suspension, and ρ_c is the resistivity of the connate water in a porous formation, assuming that the principal electrolyte is sodium chloride.

It should be emphasized that the value of ρ_{mf} is frequently different from ρ_m (the mud resistivity) and it is not permissible to use ρ_m instead of ρ_{mf}. This statement is not in agreement with the conclusions of Sherborne and Newton,[7] but has been substan-

tiated by the work of H. W. Patnode of these laboratories.

It has been stated above and it is reiterated here, that a boundary potential is wholly incapable of giving rise to current flow. However, the boundary potential is always measured when voltage determinations are made of any cell containing the boundary through which current is either flowing or is made to flow. Since flow of current through the system,

Mud//Interstitial water in porous bed/Shale/Mud,

is known to take place, it is reasonable to infer that the seat of the driving E.M.F. lies in the interaction of the shale faces with the aqueous solutions differing in salt concentration. It remains to examine the quantitative aspects of this inference.

A primary constituent of most shales is clay. Clays are known to be both complex and chemically reactive mineral substances. No quantitative work on the electrochemical properties of shales appears to have been published, but some work by Marshall[8] on the electrochemical properties of a number of relatively pure hydrogen clays appears to be germane. Marshall showed that thin membranes prepared from colloidal dispersions of several different hydrogen clays developed a potential difference between their faces if they were interposed between salt solutions of different concentrations. It was found that the potentials so developed were very sensitive to concentrations of monvalent cations, but were in general less sensitive to solutions containing divalent and trivalent cations. In particular it was found that for monovalent cations, e.g. sodium and potassium ions, the membranes tended to give E.M.F.'s which followed the Nernst equation:

$$E=\frac{RT}{F}\ln\frac{a_1}{a_2} \quad \text{- - - -} \quad 7$$

where E is the E.M.F. developed, a_1 is the activity of positive ions in the more concentrated solution, and a_2 is the activity of the positive ions in the less concentrated solution. For solutions of sodium chloride at 25° C. this reduces to:

$$E=59.15\log\frac{a_1}{a_2}\text{ millivolts} \quad \text{- - -} \quad 8$$

This relationship was found by Marshall to hold with great precision for monovalent salt concentrations less than 0.1 molal, a concentration which represents about 5800 parts per million sodium chloride.

The mechanism whereby this E.M.F. is set up is by no means clear, but the explantion may lie in the sieving action on the ions of the salt solutions which would result if there were a high negative charge on the clay lattice. Thus negative ions, e.g. chloride ions in the case of sodium chloride solutions, would be repelled by the clay and would be unable to enter the clay lattice, whereas the sodium ions would not be similarly disbarred. Thus, effectively, two Donnan potentials would be set up at the faces of the clay membrane as postulated in the membrane theories of Meyer and Sievers[9] and Teorell.[10] The total effect of such a mechanism is clearer, inasmuch as the clay membrane would then behave as a sodium electrode in a manner very analogous to that in which the well-known glass electrode for pH determinations behaves as a hydrogen electrode. Marshall's results indicate that this action can only be expected in the case of clay membranes for solutions more dilute than 0.1 molal, since at concentrations in excess of this it was found that the potential developed across the clay membranes was always very much less than that anticipated from equation 7.

The E.M.F. set up across a clay membrane, unlike a boundary potential, derives its energy from the difference in the chemical potential of the ions in the concentrated and dilute salt solutions and is therefore capable of giving rise to a small but sustained flow of current. The direction of this current flow is such as to endeavor to equalize the sodium ion concentrations on each side of the membrane, i.e. a positive sodium ion current passes effectively through the membrane from the concentrated to the dilute sodium chloride solution.

The question then is whether or not it is justifiable to extrapolate the results, which Marshall obtained using artificially prepared clay membranes, to include shales. The chemically reactive mineral constituents of the clay membrane and the shale may be assumed to be reasonably similar, but the fact that the resistivity of a clay membrane was found to be of the order of 10^5 ohm-meters compared with the order of 10 ohm-meters for a shale indicates that the heating process used by Marshall in preparing the clay membranes may have radically changed many of the properties of the clays. Nevertheless, as a first approximation it would seem that shales might also give E.M.F.'s with sodium chloride solutions which tended to follow equation 7, in which case the circuit, Mud// Interstitial water in bed/Shale/Mud, would be electrochemically equivalent to a sodium concentration cell with transport, i.e.

Na electrode/NaCl of molality m_2// NaCl of molality m_1/Na electrode.

The total E.M.F. of such a cell is the algebraic sum of the electrode potentials and the boundary potential, and is thus the sum of the potentails given by equations 4 and 7. Replacing activities of sodium chloride once again by ρ_{mf} and ρ_c, it follows that, at 25° C.:

$$E_{Total}=E+E_b$$

$$=59.15\log\frac{\rho_{mf}}{\rho_c}+11.50\log\frac{\rho_{mf}}{\rho_c}$$

$$=70.65\log\frac{\rho_{mf}}{\rho_c}\text{millivolts} \quad \text{- -} \quad 9$$

It should be pointed out that the potential across the shale and the boundary potential reinforce each other in the case of sodium chloride solutions.

Equation 9 shows that the total E.M.F. of the shale cell as it exists naturally should be capable of expression in the form (for any particular temperature):

$$E_{Total}=K\log\frac{\rho_{mf}}{\rho_c} \quad \text{- - - - - - -} \quad 10$$

This assumes that the shale behaves as a perfect sodium electrode and, consequently, obeys the Nernst equation. The form of this equation is thus the same as that of equation 1 derived by the Schlumbergers and Leonardon, but the magnitude of the constant K involved is very different.

Experimentally it is necessary to determine:

(A) Whether or not shales behave electrochemically in a manner similar to artificially prepared clay membranes.

(B) The range of solute concentration over which the Nernst equation is obeyed, assuming (A) to be generaly true.

No experiments involving simple boundary potential measurements appear to be necessary since at low and moderate solute concentrations the boundary potential should be calculable from equation 4 with an accuracy well within that obtained in electrical logging.

Experiments carried out to these ends are described below and consist of both laboratory and field studies.

EXPERIMENTAL RESULTS

Laboratory Data

For this work two principal types of shale were arbitrarily chosen, both types being obtained by coring with a diamond bit.

The first type was a Conemaugh shale of Pennsylvanian age taken from depths of between 26 and 80 feet. This shale was taken from a zone where leaching by surface waters had probably taken place.

The second type was a Woodford carbonaceous shale of Devonian (?) age taken from the West Edmond field, Oklahoma, at depths between 6808 and 6810 feet. This shale overlies the productive Hunton limestone.

Both types of shale had been air-dried before use. For purposes of measurement the following cells were set up:

$$Hg/Hg_2Cl_2/Sat.\ KCl//NaCl\ Soln.\ a_1/Shale/NaCl\ Soln.\ a_2//Sat.\ KCl/Hg_2Cl_2/Hg,$$

the concentration ratio of the sodium chloride solutions being varied as shown in Table 1. Several techniques were satisfactorily used to bring the sodium chloride solutions into contact with the cleavage surfaces of the shale, but a particularly successful method consists of cementing a flanged 24/40 male glass taper to the shale by means of a mixture comprising 100 grams of green optical pitch and 1 cc. of oil. L-shaped glass tubes are then fitted to the standard tapers to hold the sodium chloride solutions. Care was taken to make the boundary potentials between the saturated calomel electrodes and the salt solutions as reproducible as possible and to prevent contamination of the potassium chloride with sodium chloride. Most of the shale specimens used were for convenience about 3 cms. long. However, the length is not critical and has no apparent effect on the results obtained. Specimens so mounted had a total resistance of between 10,000 and 20,000 ohms and the potential could be satisfactorily measured to an accuracy of O.1 M.V. using a Leeds & Northrup Type K potentiometer. For resistances in excess of 20,000 ohms the same potentiometer was used in conjunction with a Leeds & Northrup thermionic amplifier.

The resistivities of the sodium chloride solutions were measured using a conductivity cell with platinized-platinum electrodes and a General Radio Company Type 650-A impedance bridge.

The activities of sodium ions in solutions of concentration up to 1.0 molal were estimated by making the following non-thermodynamic assumptions:

(A) That in dilute potassium chloride solutions the activities of potassium and chloride ions are equal.

(B) That the activity of the chloride ion in sodium chloride solutions is the same as that of the chloride ion in potassium chloride solutions of the same ionic strength.

Owing to the unknown accuracy of the assumptions that would be necessary, activities of sodium ions in solutions of concentration in excess of 1.0 molal were not computed.

Table 1 contains the mean values for measurements made at 20° C. Reproductibility was in general extremely good, particularly at the lower concentrations. Cracked shale specimens were unsatisfactory and were rejected. One result obtained with a mud filtrate in which the anion was principally sulfate is included.

Several tentative conclusions appear to be justifiable from the data presented in Table 1:

(A) Shales tend to give potentials with sodium chloride solutions which may be calculated from the Nernst equation.

(B) Results at low concentrations indicate that the agreement between measured and calculated values is best when ionic activities are substituted in the Nernst equation. At high concentrations activity determinations do not appear to be feasible but, both in this range and at low concentrations, the Woodford shale gives fairly good agreement between measured potentials and those calculated from resistivities. The measured value appears to be higher than the calculated except in the most dilute solutions.

(C) The range of concentration over which the Nernst equation is obeyed with reasonable accuracy appears to be wider for both the Conemaugh and Woodford shales than for any clay membranes so far prepared by Marshall.

(D) The range of concentration over which the Nernst equation is obeyed with reasonable accuracy may depend upon the nature of the shale used.

In general, for sodium chloride solutions, the laboratory experiments confirm the conclusion that the total E.M.F. of the shale cell giving rise to current flow in boreholes may be compared with the E.M.F. of a sodium concentration cell with transport.

TABLE 1

Effect of Sodium Chloride Concentrations in the E.M.F. Across Shales

Type of Shale	Activities		Molalities		m_1 as p.p.m. NaCl (approx.)	m_2 as p.p.m. NaCl (approx.)	Potential Calculated from:		Potential Measured (millivolts)
	a_1	a_2	m_1	m_2			Activities (millivolts)	Resistivities (millivolts)	
Connemaugh.....	0.0335	0.00919	0.0398	0.0101	2,320	585	32.7	33.2	32.7
Woodford.....									
Conemaugh..	0.282	0.0787	0.395	0.0995	23,200	5,850	32.2	31.2	32.2
Woodford.....									
Conemaugh	0.719	0.2856	1.0	0.4	58,450	23,380	23.3	19.1	23.0
Woodford.....									
Conemaugh.....	—	—	2.0	0.5	116,900	29,225	—	30.1	14.3
Woodford.....	—	—	2.0	0.5	116,900	29,225	—	30.1	34.2
Conemaugh.....	—	—	4.0	1.0	233,800	58,450	—	23.7	9.9
Woodford.....	—	—	4.0	1.0	233,800	58,450	—	23.7	28.5
Woodford.....	—	—	Saturated Mud Filtrate*	0.01	363,000	585	—	133.5	137.2
Woodford.....	—	—		1.0	See analysis below	58,450	—	35.4	33.8

*This filtrate was from a mud used during logging in the Brunson-Argo field in New Mexico. The approximate analysis was: Na^+ 5,172 mg. per liter; K^+ trace; Ca^{++} 680 mg. per liter; Fe^{++} Mg^{++} trace; $^+$ 340 mg. per liter; $SO_4^{=}$ 8,608 mg. per liter; Cl^- 952 mg. per liter; HCO_3^- 1,232 mg. per liter.

Field Data

If it is accepted that the E.M.F. of the shale cell with sodium chloride solutions is equivalent to a sodium concentration cell with transport, the total E.M.F. of the cell may be expressed, by again generalizing equation 9, as:

$$E_{Total} = 2.303\frac{RT}{zF}\left(1+\frac{u-v}{u+v}\right)\log\frac{\rho_{mf}}{\rho_c} \quad 11$$

Assuming that the mobilities of ca-

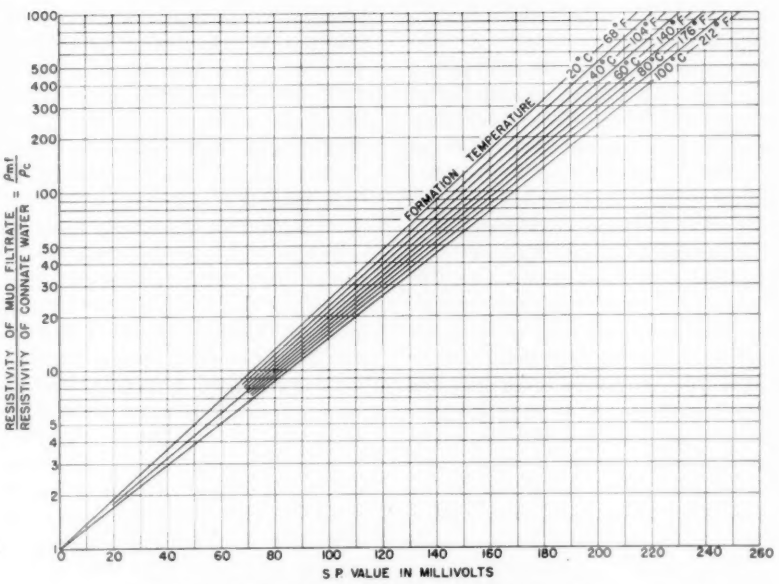
RESISTIVITY OF MUD FILTRATE / RESISTIVITY OF CONNATE WATER = ρmf/ρc
FORMATION TEMPERATURE
20° C — 68° F
40° C — 104° F
60° C — 140° F
80° C — 176° F
100° C — 212° F
S.P. VALUE IN MILLIVOLTS

FIG. 1 — RELATIONSHIP BETWEEN SELF POTENTIAL

tion and anion used in this equation are independent of concentration, it is possible to plot a series of curves for different temperatures showing the effect of the resistivity ratio ρ_{mf}/ρ_c on on the measured self potential of the shale cell. Such curves are shown in Figure 1 and refer to pure solutions of sodium chloride. In these curves an attempt has been made to consider the effect of temperature on the relative mobilities of the chloride and sodium ions.

The accuracy of these curves remains to be investigated from actual S.P. log measurements. Such an investigation normally requires knowledge of the following variables:

(A) The resistivity of the filtrate of the mud used, sodium chloride being the principal soluble electrolyte in the filtrate.

(B) The resistivity of the connate water in the porous formation corresponding to the S.P. kick being examined and an analysis showing that sodium chloride is the chief electrolyte in solution.

(C) The temperature of the formation.

It is further assumed that the thicknesses and resistivities of the porous formation and adjacent shales are such that the measured self potential is substantially equal to the true E.M.F. of the shale cell.

All these data are not easily acquired and, in fact, a reliable connate water resistivity is peculiarly difficult to obtain.

The problem is, however, greatly simplified if S.P. logs covering the same porous formation have been run with muds of two or more different resistivities. If ρ'_{mf} and ρ''_{mf} are the resistivities of two different mud filtrates, ρ_c is the unknown connate water resistivity and E′ and E″ are the peak S.P. amplitudes corresponding to the same porous formation (using the two muds), then:

$$E' = K \log \frac{\rho'_{mf}}{\rho_c}$$

$$E'' = K \log \frac{\rho''_{mf}}{\rho_c}$$

$$\text{Therefore, } E' - E'' = K \log \frac{\rho'_{mf}}{\rho''_{mf}} \quad \text{- - - - - - - - - - 12}$$

Thus, from equation 12, ρc is eliminated and the accuracy of the curves of Figure 1 can be tested using actual logs.

Such an examination was carried out on three logs of the Cypress sand section in Wayne County, Illinois. These logs were run in the same hole using muds of three different resistivities. The resistivities were altered by adding salt to the mud.

Analyses of the Cypress water from other wells showed it to be principally

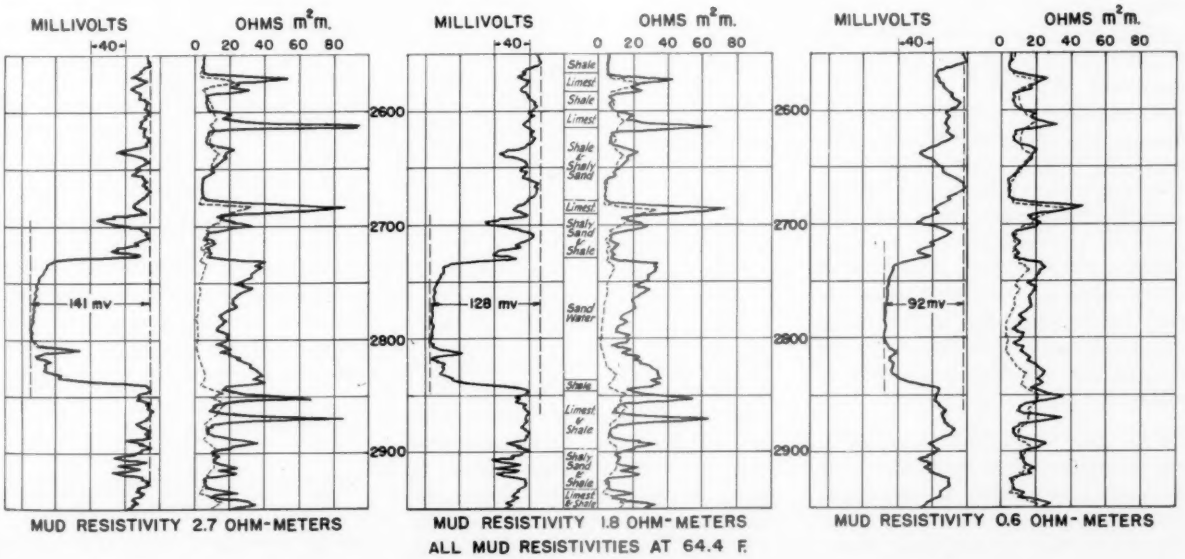

FIG. 2 — CYPRESS SAND LOGS

a sodium chloride solution, but no analysis of the Cypress water in the well logged was available.

Fig. 2 shows the three logs obtained of the Cypress sand. The shale base lines in each case have been taken, as shown, as the most positive kicks on the S.P. curve. The mud weights are given in Table 2 which summarizes all the essential data. Mud filtrate resistivities were not available and hence the mud resistivities have been used. This represents an error but, inasmuch as the mud weights were similar and the resistivities represented variations caused by salt additions to the same mud, it is believed that the comparative error will not be significant.* The borehole temperature opposite the formation was approximately 86° F. or 30° C.

TABLE 2

Data From Log of Cypress Sand

Mud Weight (lbs. per gal.)	Mud Resistivity (ohm-meters)	at Temp (°F.)	Mud Resistivity (ohm-meters)	at Temp (°F.)	S. P. (millivolts)
10.2	3.2	5'	2.7	64.4	14
10.2	1.9	61	1.8	64.4	128
10.0	0.63	61	0.6	64.4	92

From the data in Table 2 three resistivity ratios may be calculated from the mud resistivities at 64.4° F. and thus three expressions of the kind given in equation 12 may be derived.** Table 3 contains the numerical evaluations.

It will be seen that in this example the agreement between the S.P. values obtained from the log and those obtained from the calculated values plotted on Figure 1 for a formation temperature of 86° F. are in excellent agreement. It appears that for the relatively dilute salt solutions comprising the mud filtrates used, the shale adjacent to the Cypress sand gives potentials which follow the Nernst equation. Whether the Nernst equation holds for the cells involving the mud filtrates and the much more concentrated saline solution which constitutes the connate water, can be determined by calculating the connate water resistivity from the three S.P. values obtained.

* The mud resistivities recorded on the headings of the three logs were converted to a common temperature of 64.4° F. for comparative purposes. For this conversion the well-known curves relating the resistivity and concentration of aqueous sodium chloride solutions were used.

** It should be noted that the mud resistivities could have been reduced to any convenient temperature, not necessarily 64.4° F., since the ratio of the resistivities, measured at a particular temperature, of any two sodium chloride solutions is almost independent of the temperature of measurement. The resistivity of the connate water will, of course, be determined for the temperature corresponding to that at which the mud resistivity was determined.

The connate water resistivities are shown in Table 4 to be in good agreement, which indicates that the calculated Nernst equation constant holds good. It should be noted that the resistivity values obtained are relative and not absolute in this case, since mud resistivities and not the more accurate mud filtrate resistivities were used in the calculations. It can be seen also from Table 1 that if the measured value of S.P. is approximately the theoretical E.M.F. of the shale cell (the case in the thick Cypress sands considered), the value of the connate water resistivity calculated may be too low.

TABLE 3

Comparison of Observed and Calculated S.P. Differences

Resistivity Ratio	S. P. Difference (millivolts)	S. P. from Fig. 1 (millivolts)
$\frac{2.7}{1.8}=1.5$	141–128=13	14
$\frac{2.7}{0.6}=4.5$	141—92=49	48
$\frac{1.8}{0.6}=3.0$	128— 92=36	35

This would be the case with a shale of similar properties to the Woodford shale since the substitution of resistivities for ionic activities represents an error. This error varies with the concentrations of the two sodium chloride solutions, being greatest for solutions of high concentration. Another factor affecting the absolute value of the calculated connate water resistivities would be the existence of any constant error in the S.P. values read from the three logs.

The Cypress sand example quoted represents in every way a very nearly ideal case for application of the quantitative shale cell theory outlined above. It is instructive, however, to examine the relationship between calculated and observed potentials for a number of porous beds under conditions where the nature of the salinity of the mud given in Table 2 which summarizes filtrate and connate waters are less well-known. Such an example would have more in common with ordinary log interpretation.

Available for this purpose were two logs run with muds of different resistivity in an 11,000 ft. well in Kern County, California. As before the muds used were of the same weight (10.5 lbs. per gal.) and hence the mud resistivity to mud filtrate resistivity correction could be neglected for comparative purposes. The bottom hole temperature measured in this well was 220° F. or 105° C. Making the assumption that the geothermal gradient in the well is uniform, it is possible to estimate the temperature of porous beds at any depth. This method was used for the temperatures listed in Table 5. The mud resistivities in the two runs, reduced to a common temperature of 64.4° F., were 2.1 ohm-meters and 0.62 ohm-meters. The resistivity ratio was thus $2.1/0.62=3.4$. In Table 5 are plotted potentials calculated from this ratio for the estimated temperatures of the corresponding porous beds. Only those beds were considered where the measured potentials were believed to be substantially equal to the total potentials of the appropriate shale cells. The calculated potentials are compared with the difference in the measured potentials as for the Cypres example. Finally the connate water resistivities for

TABLE 4

Calculation of Connate Water Resistivity for Cypress Sand

S. P. (millivolts)	Resistivity Ratio from Fig. 1	Mud Resistivity / Ratio	Connate Water Resistivity (ohm-meters at 64.4° F.)
141	82	$\frac{2.7}{82}$	0.0329
128	55	$\frac{1.8}{55}$	0.0327
92	18	$\frac{0.6}{18}$	0.0334

each porous bed computed from the two logs are listed for purposes of comparison.

In Figure 3 the observed S.P. differences from the two logs are plotted against the temperatures of the corresponding porous beds. The straight line represents calculated potentials over the same temperature range for the resistivity ratio 3.4. It will be seen that, although there is a considerable scatter, the straight line represents a fair curve through the plotted points.

On the whole the results given in Table 5 and Figure 3 indicate that the shale cells tend to yield potentials following the Nernst equation. The agreement between calculated and measured potentials, considering the assumptions made regarding the nature of the geothermal gradient and the type of fluids in the porous beds is, in fact, very encouraging. The last result in Table 5 (10,685 to 10,790 feet) is particularly interesting inasmuch as it shows a reversal of the S.P. kick when using the low resistivity mud, but no reversal with the high resistivity mud. This, of course, results from the fact that the connate water resistivity lies between

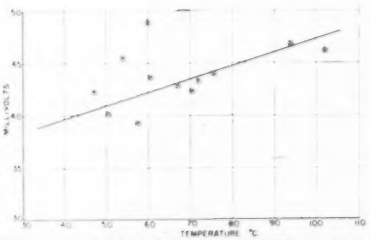

FIG. 3 — COMPARISON OF OBSERVED AND CALCULATED SELF POTENTIALS, KERN COUNTY WELL.

the two mud resistivities. The negative sign ascribed to the reversed potential in Table 5 is only relative to the remaining values which are listed as positive for convenience.

The connate water resistivities calculated from the two logs for the twelve porous beds considered are in reasonable harmony. The absolute connate water resistivities will be different from these values for the same reasons as given above for the Cypress sand example, but it is apparent that the saline content of these beds is considerably smaller than in the Cypress example. The Nernst equation appears to be applicable in every case.

APPLICATIONS TO CONNATE WATER DETERMINATION

The quantitative evaluation of the shale cell potential offered here has obvious applications to the determination of connate water content of oil sands from electrical log data. Assuming that the Nernst equation holds for the S.P. kick corresponding to a porous sand with intergranular porosity containing both connate water and hydrocarbons, the connate water resistivity, ρ_c, may be determined from the mud filtrate resistivity and measured S.P. using the curves in Figure 1. For an accurate connate water calculation it is necessary to know:

(A) The geothermal gradient in the hole.

(B) The mud and mud filtrate resistivities at specified temperatures. It is recommended that all electrical logs show the latter quantity on the log heading as a matter of routine.

(C) The true bed resistivity.

(D) The true resistivity of the invaded formation surrounding the borehole or the formation factor of the bed experimentally determined from cores. See Archie's paper.[11]

From the geothermal gradient the approximate temperature corresponding to the bed of interest is obtained. This figure permits the appropriate curve on Figure 1 to be selected for the determination of ρ_c.

The formation factor, F, if not known from cores can be calculated from a true value of the invaded resistivity, ρ_t, as follows:

$$F=\frac{\rho_t}{\rho_{mf}}$$

The resistivity of the sand 100% filled with connate water, is ρ_w, is then

$$\rho_w=F\rho_c$$

The resistivity index is derived by dividing the true bed resistivity, ρ_t, by ρ_w, and the connate water content W, is obtained from this index using the well-known relationship published by Wyckoff and Botset[12] and others,

$$\frac{\rho_t}{\rho_w}=\frac{1}{w2}$$

At present most electrical logs do not record all the data required for this method. It is hoped that this situation will be corrected in the future.

CONCLUSIONS

The analysis of the shale cell potential given above has been shown by both laboratory and field tests to be essentially correct. It seems possible that all shales have electrochemical properties of the same nature as those shales arbitrarily selected for examination in these studies but, until the method has been applied to the analysis of logs from as many wells as possible throughout the world, it is impossible to deny that serious anomalies may exist. Comparison of computed potentials or resistivities with relaible experimental data will ultimately determine this point. It should be pointed out that concentrations of dissolved salts frequently observed in connate waters represent molalities far outside the range of dilute solutions for which most electrochemical formulae have been derived. Thus any relationships based on classical thermodynamics must represent approximations when applied to many electrical log data. Results so far obtained indicate, however, that these errors may not be very serious from the practical standpoint.

The effects of salts other than sodium chloride in solutions in the mud filtrate or connate waters represent a problem which requires further study. For connate waters which are predominantly sodium chloride and for mud filtrates in which the cations are principally sodium, the relationships expressed by Figure 1 may still be satis-

TABLE 5

Comparison of Observed and Calculated Data, Kern County Well

Depth Ft.	Temp. °C.	Self Potential (millivolts)		S P Difference		Calculated Connate Water Resistivity (ohm-meters at 64.4° F.)	
		Mud A (2.1 ohm-meters)	Mud B (0.62 ohm-meters)	Measured (millivolts)	Calculated (millivolts)	Mud A (2.1 ohm-meters)	Mud B (0.62 ohm-meters)
2,955–3,040	47.0	51.3	9.0	42.3	40.6	0.45	0.48
3,530–3,540	50.5	52.5	12.3	40.2	41.0	0.43	0.43
4,035–4,100	54.0	65.5	20.0	45.5	41.4	0.30	0.34
4,477–4,497	57.5	60.7	21.4	39.3	41.8	0.35	0.34
4,777–4,794	60.0	73.3	24.4	48.9	42.2	0.24	0.30
4,896–4,907	60.5	69.3	25.6	43.7	42.2	0.28	0.30
5,888–5,897	67.0	77.5	34.6	43.1	43.1	0.22	0.23
6,335–6,350	70.5	59.4	17.1	42.3	43.5	0.38	0.38
6,552–6,571	72.0	69.3	26.0	43.3	43.7	0.29	0.30
7,005–7,030	75.5	73.4	29.4	44.0	44.2	0.26	0.27
9,495–9,580	94.0	82.5	35.7	46.8	46.6	0.22	0.23
10,685–10,790	102.0	40.4	— 5.7	46.1	47.5	0.71	0.73

factory. In the case of connate waters in which the sodium ion is not the predominant cation the relationships must break down. Laboratory and field studies alone will elucidate these complications. These studies are continuing.

ACKNOWLEDGMENTS

The writer is indebted to Mr. H. W. Patnode for his assistance in carrying out many of the laboratory experiments described and to Mr. A. C. Godbold and Mr. G. W. Ledingham for drawing his attention to suitable logs for use as examples. The writer's thanks for permission to publish this paper are due to Dr. Paul D. Foote, Executive Vice President, Gulf Research & Development Company.

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DISCUSSION

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By Milton Williams, Humble Oil & Refining Co., Houston, Texas

Dr. Wylie has made an interesting approach to the solution of an intriguing and difficult problem. I wish to take issue however, with his implication that the shale, or Mounce, potential results from a mechanism which is electrochemically equivalent to a sodium concentration cell with transport.

Such a mechanism takes no cognizance of the fact that shale or other collidal matter is a requisite to the development of the Mounce potential. It may be shown experimentally that only the expected liquid junction potential, usually of the order of 10 millivolts, is found when the two solutions of different salinities are separated by a barrier of low permeability non-colloidal material, such as cellophane, or fritted glass. On the other hand, naturally occurring shales or sandy shales of comparable permeability usually give relatively high Mounce potentials.

Following the same thought further, Dr. Wyllie's concept gives only parenthetical consideration to the variation of the Mounce potential with variation of the character of the shale. I have had occasion to determine the values of the Mounce potential for many shale samples, and have observed that the magnitude of the potential depends in a large measure upon the nature of the shale. Generally, the more hydrophilic the clay, the greater is the Mounce potential. Dr. Wyllie's Figure 1, which gives no recognition to this dependence on the character of the shale, may therefore be misleading.

Another objection to Dr. Wyllie's concept is that it may be shown experimentally that the Mounce potential is developed even when there is no ion common to the salts dissolved in the fluids separated by a shale barrier. For example, a shale barrier interposed between a relatively concentrated solution of sodium chloride and a dilute solution of, say, thorium nitrate, yields a Mounce potential of normal polarity and only slightly less magnitude than would be obtained if the thorium nitrate solution were replaced by a sodium chloride solution of the same molarity. If the molarity of the thorium nitrate solution be increased, and made greater than that of the strong salt solution on the other side of the shale, the polarity of the cell is reversed.

It is difficult to reconcile this behavior, as well as the dependence of the potential on the colloidal properties of the shale with the concentration cell concept. It appears likewise improbable that the explanation of the Mounce potential lies in the mechanistic concept of a shale barrier permeable only to particular ions.

An explanation of the Mounce potential which seems logical to me, and which is in keeping with experimental observations is briefly, as follows:

In its normal state, shale is in equilibrium, with respect to adsorption, with the saline water contained in its interstices. Chloride ion is more strongly adsorbed that sodium, so that the former is constrained by adsorptive forces, while the latter constitutes the contra-ion. When the shale is placed in contact with water, or with a dilute salt solution, a new adsorption equilibrium is approached. In attaining this new equilibrium, the sodium contra-ions may be supposed to diffuse away from the clay particles before the corresponding chloride ions are desorbed. This "leading" of the contra-ions should give rise to a potential effect, which may well be the Mounce potential.

As a corollary, the pH of the dilute solution should rise initially, then de-

crease as the initial migration of sodium ions is followed by desorption and migration of the chloride ions. Experimental work has indicated that such a change in PH does take place.

It might also be expected that colloidal materials other than clays would, under proper conditions, exhibit a Mounce potential. To test this, the compressed coagulum from a positive hydrous ferric oxide sol, which contained a high concentration of sodium chloride, was placed between strong and weak salt solutions. A Mounce potential of about 30 millivolts was observed, with the more dilute solution negative. A repetition of this test, using a coagulum of very coarse hydrous-ferric oxide, gave only a negligible potential.

The concept of the Mounce potential arising from the delayed migration of the more strongly adsorbed ions implies that the phenomenon is, in a relative sense, transient. That this is so is confirmed by experience both in the laboratory and, by numerous observations of gradually diminishing self-potentials, in logging practice in the field.

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By Hubert Guyod, Well Logging Consultant, Houston, Texas

The paper's title conveys the impression that bore hole potentials comprise one or more significant components in addition to the electrochemical effect. This, however, does not seem to be substantiated by the experimental results discussed by the author in his paper, nor by some of the recent literature. A short statement expressing the author's view on this point would be of interest.

In view of the rather complete and interesting discussion offered by the author on the potential graphs from the Cypress sand section in Wayne County, Illinois, it would be of great value to other workers that the interstitial water analysis of this sand be included in the paper.

☆

Author's Reply to Milton Williams and Hubert Guyod

Mr. Williams does not seem to be in accord with my concept of the mechanism of the electrochemical E.M.F. He does not, apparently, suggest any quantitative alternative explanation for the experimental observations made. However, it may be of interest to consider some of the experimental observations and theoretical comments made by Mr. Williams in the light of the theory proposed in my paper.

The concept of a sodium concentration cell with transport as a quantitative explanation for the observed potentials recorded when the soluble electrolytes in the borehole and the connate water are sodium chloride is believed to be fundamentally correct. This case is probably the most important one in practice and was thus taken as a good example for use in a preliminary paper. It should be noted that if the anion of mud filtrate is not the chloride ion the effect on the total E.M.F. observed is twofold. Firstly the activity/resistivity relationship of the mud filtrate in terms of sodium ion activity and the resistivity of a sodium chloride solution is altered, and secondly, the value of the boundary potential between the mud filtrate and the sodium chloride in the connate water is no longer the simple relationship given in equation 6 above. For common mud filtrate anions such as sulfate, carbonate and bicarbonate, no serious activity error ensues as the appropriate calculations will show. The Henderson equation given as equation 2 above indicates that the predominant boundary potential influence, when the salinity of the connate water greatly exceeds that of the mud filtrate, is the principal salt in the connate water. Thus for the case of Na^+ as the principal cation in the mud filtrate and sodium chloride as the principal electrolyte in the connate water, the curves given in Figure 1 are essentially accurate.

As regards the existence of colloidal material in the shale to act as a source of the observed potential this is not disputed, except that the material need not necessarily be colloidal to produce analogous electrical effects. See, for example, the work of Marshall[1] using natural zeolites. Many materials which have a charged lattice will give rise to electrochemical potentials of the type under consideration. In this connection the papers by Sollner[2, 3, 4] concerning membrane potentials in general and those across oxidized collodion membranes, in particular, provide an excellent introduction to the subject. In the case of shales, the fixed anionic charges which give rise to the observed potentials, according to the theory of Meyer and Sievers and of Teorell, are almost certainly those resulting from dissociation of the cations of the clay minerals. Any membrane made from a charged sol will similarly give rise to a potential which will tend to the Nernst potential. The magnitude of the potential will, however, depend upon the charge on the sol forming the membrane and the degree of anionic conductivity within the membrane. Negatively charged membranes will be similar to shales, while positively charged membranes will respond to the activities of the anions present in the solutions in contact with them.

It is fully recognized that shale barriers will give rise to potentials when they separate solutions containing no common ions. These cases are covered by the theory of Meyer and Sievers and of Teorell quoted above. The potential is essentially dependent for sign and magnitude on the ratio of the activities of the cations on either side of the shale barrier and their relative mobilities within the shale barrier. On this basis Mr. Williams' results with thorium nitrate and sodium chloride could probably be explained both qualitatively and quantitatively.

The pH effects noted by Mr. Williams would follow from the fact that the current through the shale is mainly carried by cations, frequently sodium ions. Thus migration of these cations into the dilute solution will raise the pH. Correspondingly the pH in the concentrated side goes down, and in relatively small volumes of solution, if they are not changed periodically, some of the current is eventually carried to the low concentration side by hydrogen ions, resulting in a subsequent pH decrease on that side.

The fact that the Nernst potential may not be attained at high concentrations of electrolytes if the thermodynamic charge on the active materials in the shale is insufficient, was pointed out in my paper. The Conemaugh shale examined was a laboratory example of this effect and doubtless there are many others. A similar effect arises if there are physical imperfections, such as cracks, in the small shale samples examined. This makes laboratory work on the problem difficult although fractures can generally be detected. Calculations made from electrical logs tend to show that shales in situ frequently give closer approximations to the Nernst potential than do small laboratory samples of the same shale. This aspect of the problem needs further elucidation by the study of appropriate field data.

These references are listed at end of author's reply.

The falling off of potential with time which is frequently observed in boreholes may be due to equalization of the concentrations of the mud filtrate and connate water electrolyte concentrations caused by current flow in the borehole. The effect of mud filtrate invasion of the formation with time, which also leads to diminuition of the S.P., has been ably demonstrated by Doll in the paper listed above, and it may be this effect which is predominant, since the solution volumes are relatively enormous, and concentration changes will thus be small.

It seems unfortunate that the excellent work of Mounce and Rust has led to the original work of C. and M. Schlumberger and E. G. Leonardon being largely forgotten. On re-reading the contributions of the latter workers, I would like to pay tribute to the fact that their original paper[5] these workers showed that impervious materials such as shales and clays gave rise to an electromotive force which caused a current to flow from a porous bed through the impervious material to the mud in the borehole. They were thus responsible for the original shale cell concept, or electrochemical potential effect, in well logging, which Mounce and Rust subsequently re-emphasized so effectively. I must apologize for not making this clear in my introduction.

Mr. Guyod's remarks are singularly germane. In writing my paper I have deferred to the rather widely held belief that in certain cases streaming potential or electrokinetic effects are of importance. It is hoped to deal with some aspects of this problem in a later paper, but I may say here that in rotary drilled wells it is my present belief that streaming potentials do not appear to be of very significant moment and to a first approximation, the S.P. may be treated as a simple electrochemical effect.

The Cypress sand example quoted is of considerable interest. It was pointed out in the paper that the absolute value of the connate water resistivity computed was not accurate, although the agreement in the three values obtained in Table IV showed that the Nernst equation was being obeyed. The mean resistivity of 0.033 ohm-meters at 64.4° F. represents a completely saturated sodium chloride solution, whereas the best information we possess regarding the salinity of the connate water in this sand indicates a value of about 150,000 p.p.m. This error results from the employment of resistivities instead of activities in the calculations, since the ratio on the ordinate scale on Figure 1 is properly one of activities. Recalculating on the basis of computed activities gives a connate water salinity of 200,000 p.p.m. This value is obtained using the mud resistivity to compute the mud activity and hence, from the ratios obtainable from Figure 1, the connate water activities. A better value would probably have been obtained had the mud filtrate resistivity been available. The inaccuracies resulting from the use of resistivities instead of activities become progressively more serious as connate water salinities exceed about 60,000 p.p.m.

[1]C. E. Marshall: The Use of Zeolitic Membrane Electrodes. J. Phys. Chem. (1939), *43*, 265.
[2]Karl Sollner: The Nature of Physicochemical Membranes as Physicochemical Machines: Preparation and Properties of Membranes of Highly Pronounced Electrical Properties. J. Phys. Chem (1945), *49*, 47.
[3]Karl Sollner: The Physical Chemistry of Membranes with Particular Reference to the Electrical Behavior of Membranes of Porous Character II. J. Phys. Chem. (1945), *49*, 171.
[4]Karl Sollner: The Physical Chemistry of Membranes with Particular Reference to the Electrical Behavior of Membranes of Porous Character III. J. Phys. Chem. (1945), *49*, 265.
[5]Reference 2 of the paper under discussion, page 278.

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